REPUBLIC OF MALAWI

MINISTRY OF AGRICULTURE

BIDDING DOCUMENTS

FOR

PROCUREMENT OF

CONSTRUCTION OF SECONDARY CANALS AND REMAINING WORKS IN PHASE I AREA

PROJECT NAME: SHIRE VALLEY TRANSFORMATION PROGRAM-1

ICB No: **MW-MOAIWD-300926-CW-RFB**

EMPLOYER: MINISTRY OF AGRICULTURE (MoA)

COUNTRY: **MALAWI**

Issued on: **MAY 2023**

VOLUME VI: SPECIFICATIONS

Specification

Table of Contents

1. GENERAL

1.1 GENERAL WORKS

1.1.1 General Information

The Government of Malawi is implementing the Shire Valley Transformation Program-1 in Chikwawa District, southern region of Malawi which is being financed by World Bank (WB) and African Development Bank (AfDB). The development objective of the Shire Valley Transformation Program is to increase agricultural productivity and commercialization for targeted households in the Shire Valley and to improve the sustainable management and utilization of natural resources.

Among the five components in this project, the first component, irrigation service provision will finance the works, goods and services necessary to develop bulk irrigation and drainage infrastructure of the SVTP 1. This includes preparation of detailed designs, construction supervision and quality assurance, construction of the physical bulk water conveyance and main distribution system, major drainage and access roads. The component mainly consists of two sub-components: infrastructure development and support to effective and sustainable irrigation management, operation and maintenance.

The project sites are located in Chikwawa District. The location of sections is more specifically described with coordinates in the drawings.

Scope of Works for Phase I area are divided into i) Construction of Intake+6km (MC1) and ii) Construction of 2nd section of MC1(27km)+MC2(18km), and iii) Construction of MC3, Secondary Canals and Remaining Works in Phase I Area (the tasks which are corresponding to this Bid). The former two tasks are currently under construction. The third task was divided into two tasks as follows in consideration of the scale of the task and the reduction of the construction period.

- Construction of MC3
- Construction of Secondary Canals and Remaining Works (the tasks which are corresponding to this Bid)

Among them, the task of this bid is limited to Construction of Secondary Canals and Remaining Works, and the task of Construction of MC3 is carried out through other bids.

1.1.2 Brief Description of the Contract Works

(a) Scope of Works

Main features of the project are presented in the following tables.

No	Work Items	Details			
		19 Pipelines + 2 Pump Station			
		SC Name	Pipe Type	L (m)	D (mm)
1	Secondary Canals And Access Roads	1A	HDPE	1,200	630
		1	HDPE	600	1,000
		1	HDPE	3,800	900

1	HDPE	3,820	800
2	Steel Pipe	1,750	1,400
2	Steel Pipe	1,850	1,400
2	Steel Pipe	1,976	1,400
2	Steel Pipe	3,524	1,200
2	Steel Pipe	3,950	1,200
2	Steel Pipe	1,458	1,000
2-1	Steel Pipe	1,000	1,100
2-2	HDPE	454	630
3	HDPE	1,300	560
4	HDPE	808	800
5	HDPE	750	630
6	HDPE	1,100	900
7	HDPE	50	710
8	HDPE	50	800
9	HDPE	50	900
9	HDPE	2,700	900
9	HDPE	3,250	710
10	HDPE	500	450
11	HDPE	500	500
12	HDPE	396	710
13	HDPE	650	500
14	HDPE	50	400
15	HDPE	50	400
16	HDPE	100	400
17	HDPE	1,000	800
18	Steel Pipe	1,000	1,000
18	HDPE	1,800	1,000
18	HDPE	1,909	900
19	Steel Pipe	1,500	1,300
19	Steel Pipe	1,500	1,100
19	Steel Pipe	750	1,000
19	HDPE	4,006	560
19-1	HDPE	1,450	900
PS-1	HDPE	50	400
PS-29	HDPE	100	400

23 Maintenance Roads (Murram Paved Road: MPR)

Road Name	Road Type	L (m)	WxH
1A	MPR	1,200	5.0m×0.5m

		1	MPR	8,220	5.0m×0.5m
		2	MPR	14,508	5.0m×0.5m
		2-1	MPR	1,000	5.0m×0.5m
		2-2	MPR	454	5.0m×0.5m
		3	MPR	1,300	5.0m×0.5m
		4	MPR	808	5.0m×0.5m
		5	MPR	750	5.0m×0.5m
		6	MPR	1,100	5.0m×0.5m
		7	MPR	50	5.0m×0.5m
		8	MPR	50	5.0m×0.5m
		9	MPR	6,000	5.0m×0.5m
		10	MPR	500	5.0m×0.5m
		11	MPR	500	5.0m×0.5m
		12	MPR	396	5.0m×0.5m
		13	MPR	650	5.0m×0.5m
		14	MPR	50	5.0m×0.5m
		15	MPR	50	5.0m×0.5m
		16	MPR	100	5.0m×0.5m
		17	MPR	1,000	5.0m×0.5m
		18	MPR	4,709	5.0m×0.5m
		19	MPR	7,756	5.0m×0.5m
		19-1	MPR	1,450	5.0m×0.5m

		Items	Quantities	Locations
2	Offtake Structures, Divergences, Control Valve and Flowmeter Structures, Pump Stations	Offtake structures	17	SC1A, SC1-6, SC12-20 (From MC1 and 2)
		Valve & Flowmeter Structures	20	Control Valve (Offtake point)
			65	Distribution Valve (In the Farm)
			20	Flowmeter (Offtake point)
		Pump Stations	2	Irrigation Sector 3-1 and 16-2
		Air Valve Structures	44	SCs
		Sediment Eject Structures	9	SCs
		Night Storage Reservoirs	15	Zone I-1
			14	Zone A

<table>
<tr>
<td>3</td>
<td>SCADA System</td>
<td>
<table>
<tr><td colspan="3">Tele-metering and Tele controlling system</td></tr>
<tr><th>Items</th><th>Quantities</th><th>Locations</th></tr>
<tr><td>Valves</td><td>20</td><td>SCs(20)</td></tr>
<tr><td>Flow Meters</td><td>25</td><td>Intake(2), MC2(2), MC3(1), SCs(20)</td></tr>
<tr><td>WL Sensors</td><td>7</td><td>Intake(1), MC1(3), MC2(3)</td></tr>
<tr><td>CC-TV</td><td>4</td><td>Intake(1), MC1(1), MC2(2)</td></tr>
</table>
</td>
</tr>
<tr>
<td>4</td>
<td>Flood Protection</td>
<td>
<table>
<tr><td colspan="3">Three Dykes</td></tr>
<tr><th>Items</th><th>Lengths (m)</th><th>Locations</th></tr>
<tr><td>Dyke No.1</td><td>1,696</td><td>Irrigation Sector 14-1</td></tr>
<tr><td>Dyke No.2</td><td>1,744</td><td>Irrigation Sector 13-1</td></tr>
<tr><td>Dyke No.3</td><td>2,427</td><td>Irrigation Sector 18-2&3</td></tr>
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(b) Construction Period

The duration of the construction contract shall be **28 months**.

1.1.3 Abbreviations, Acronyms and Nomenclature

In this Specification the following abbreviations have the meanings hereby assigned to them:

(a) Standards and Organizations

Each and every part of the Works shall be designed, constructed, manufactured, tested and installed in accordance with an internationally recognized Standard, Code of Practice, or Regulation applicable to that part of the Works.
Such standards, etc. shall include:

(1) British Standards (BS)
(2) International Organization for Standardization (ISO)
(3) Other national or international or other authoritative standards equivalent or superior to those designated in the Specifications. The Contractor shall demonstrate to the Engineer's satisfaction the equivalence or superiority of any item of Works supplied to such alternative standards.

All standards shall be the latest published and shall include amendments which are current at the date of manufacture or construction (as applicable). In the case of category (4) approval must be given in writing by the Engineer, and the Contractor shall familiarize himself with the requirements of these standards. Standards may be denoted by abbreviations indicating the name of the issuing authority, as follows:

ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BS	British Standards
DIN	Deutches Institute for Normung

ISO	International Organization for Standardization
IEC	International Electrotechnical Commission
BSCP	British Standard Code of Practice
BSP	British Standard Pipe (Thread)
UK	United Kingdom of Great Britain and Northern Ireland

In the case of conflict between the various regulations, the regulations of the appropriate authority in Malawi shall take precedence.

(b) Dimensions and Units

mm	millimeter
cm	centimeter (1 in. = 2.54 cm)
m	meter
km	kilometer
mm^2	square millimeter
cm^2	square centimeter
m^2	square meter
ha	hectare or 10,000 square meters
l	liter
mgd	million gallons per day
mg/l	milligramme per litre
g/l	gramme per litre
cc	cubic centimeter
m^3	cubic meter
g	gram (1 lb = 453.6 g)
mg	milligram
kg	kilogram
tonne	1,000 kilograms
N	newton
kN	kilonewton
h	hour
l/s	litre per second
m^3/s	cubic meter per second
kg/cm^2	kilogram per square centimeter
kg/m^3	kilogram per cubic meter
kgf	kilogramme force
ºC	degrees Celsius
%	per cent
‰	per thousand.

(c) Others

NPSH	Net Positive Suction Head
rpm	Revolutions per minute
A	amp
mA	milliamp
kA	kilo ampere
V	volt
kW	kilowatt
kWH	kilowatt hour
kVA	kilovolt amp
Hz	hertz (cycles per second)

SI	International System of Units
O&M	Operating and Maintenance
IDA	International Development Association
API	American Petroleum Institute
IEE	Institution of Electrical Engineers
MOW	Ministry of Water
DN	nominal diameter
GMS	galvanized mild steel
MDPE	medium density polyethylene
No.	number
NP	nominal pressure
OD	outside diameter
GRP	Glass fibre reinforced polyester
EPDM	ethylene propylene rubber
FSD	full scale deflection
PVA	polyvinyl acetate
NTU	nephelometric turbidity unit
m.a.s.l.	meters above sea level
RSJ	rolled steel joist
HRC	High rupturing capacity
DC	direct current
XLPE	cross linked polyethylene
LV	low voltage
SWA	steel wire armoured
LSF	low smoke and fume
PE	polyethylene
IS	intrinsically safe

1.1.4 Contractor's Responsibility for Design

Subject to the requirements of this Specification the Contractor shall be responsible for the general and detailed design of the complete equipment to be provided and for the dimensions and arrangements of the various parts.

The Contractor shall be responsible for the appropriateness of hydrological calculations of the water distribution system on the roads where the actual pipes shall be laid.

The design, construction and finish of the complete equipment supplied under this Contract shall be according to first class engineering practice and each item of equipment shall be in every way suitable for continuous operation over the full range of duties.

1.1.5 Contractor's Representation on Site

At least one named responsible senior representative (Agent) of the Contractor shall be immediately available at all times and he shall be on the Site during normal working hours. In the absence of the Contractor's representative a deputy shall be appointed whose name shall be notified to the Engineer at least one day before absence of the Agent and at least three days before any absence exceeding one day. To the Agent (or his deputy) shall be delegated full authority to confer with the Engineer or delegated representative and to take all steps and to issue all those instructions which may be required in an emergency to ensure the safety of all personnel and the Works and of all the Employer's and other property on the Site and in the immediate vicinity thereof.

The Contractor shall provide and maintain at the Site, offices for the use of his representative, to which written instructions by the Engineer can be delivered. Any instructions delivered to such offices shall be deemed to have been delivered to the Contractor. Such offices shall be erected before commencement of the Works.

1.1.6 Personnel

The Contractor shall ensure that at least one senior member of his field supervisory staff, who is experienced in such operations and fluent in English or languages of his labourers, is on site throughout the whole duration of the work.

The Contractor shall also ensure that all necessary skilled artisans for the operation of all his Works are on site throughout the work. The Contractor shall obtain the approval of the Engineer not less than 48 hours before the commencement of the work in respect of each of such personnel. To gain this approval the Engineer may require that such operative is tested in the performance of his duties in the operation of the Works for which he is in attendance. In particular this requirement shall apply to all welders, pipe-cutters and crane operators.

The Contractor shall ensure that an adequate number of labourers are in attendance upon the site during the period of the work.

1.1.7 Assistance to the Engineer

(a) General

The Contractor shall render such assistance with facilities, labour, and materials as at any time may be required by the Engineer's representative directly or indirectly in connection with the works.

The costs of such assistance shall be borne by the Contractor if such assistance is intended for or provided for or specified in the contract; if any assistance is required by the Engineer's representative which is not so intended and not provided for and not specified, then the cost of such assistance shall be borne by the Employer.

The assistance to the Engineer's representative includes, but not by way of limitation, the items in the following sub-chapters.

(b) Protective Items

The Contractor shall provide for the use of the Engineer's Representative and his principals, employees and agents and such other persons as the Engineer authorises adequate protective items such as gumboots, waterproof top-coats, first-aid equipment, life-jackets, hard hats and other safety equipment as required by the Engineer in connection with the Contract.

(c) Care of Public Utility Services

For the purpose of these Specifications public utility services (hereinafter referred to as "public utilities") mean:

(1) Water lines complete (incl. water meter boxes, valve boxes, fire hydrants etc.).

(2) Wire lines complete (telephone wires, poles etc.).

(3) Power lines, both high tension and low tension, complete (masts etc.).

(4) Cable ways.

(5) Street Lighting.

1.1.8 Office Accommodation, Equipment and Services for Engineer

(a) General

Within 2 weeks of the commencement of work on Site by the Contractor, and throughout the execution of the Works, including the Defects Liability Period, the Contractor shall maintain the office accommodation, equipment and services for the Engineer.

(b) Site Office

The Contractor shall provide for the duration of the Contract the following survey equipment.

(1) One modern levels of an approved type

(2) Two levelling staves (metric)

(3) Two 200 m metal measuring tapes

(4) Four 30 m metallic line tapes

(5) Six 10 m retractable pocket tapes

(6) 10 no. ranging rods

The Contractor shall provide all labour and assistance as may be required by the Engineer for checking the Contractor's setting out.

The Contractor should provide the site office for the construction company and the Engineer, and should provide the furniture and office items. The area for the site office should be provided by the Government of Malawi (GoM). The Contractor should build the site office through discussion with GoM about the location of the office. The fence for the site office should be provided, and the area should be provided the enough area to keep the construction materials.

The size of site office: The Contractor should decide the size of the site office and build it through discussion with GoM and the Engineer after decides the member of employee at the construction site.

The item list for the site office: The Contractor should provide the office items depend on the size of the site office, and the items should be provided through discussion with GoM and the Engineer.

1.1.9 Information to be Supplied by the Contractor

Within 30 days of the Letter of Acceptance, the Contractor shall submit to the Engineer for his approval a detailed program in accordance with the Conditions of Contract.

Within 30 days of the Start Date, the Contractor shall submit to the Engineer for approval of drawings for construction and drawings showing details of reinforced concrete structures.

All drawings, technical specifications and other information shall be in English and shall be submitted the number of copies, which is discussed with the Employer and Engineer, for approval. Subsequent to approval being given, the Contractor shall supply the number of copies, which is discussed with the Employer and Engineer, to the Engineer. Drawings and Specifications which have been approved by the Engineer shall not be departed from without the approval of the Engineer to the change.

Approval by the Engineer of drawings, specifications and other information shall not relieve the Contractor from any obligation under the Contract.
All drawings submitted by the Contractor shall bear:

- The title of the Drawing
- The scale
- The date
- The name and references of the Contractor
- A drawing number in a logical sequence
- A revision number (where applicable)

1.1.10 Level Datum

All levels shall be referred to the National Datum and the Contractor shall obtain in writing from the Engineer the location and value of the permanent bench marks to be used to control the works.

Before the commencement of construction work the Contractor shall establish at each site in a position to the approval of the Engineer, a steel datum peg which shall be securely concreted in. The level of this peg shall be established and agreed with the Engineer and all levels used in the construction of the Works shall be referred to this established datum. The correctness of this established datum shall be checked at regular intervals during the construction period and agreed with the Engineer.

1.1.11 Levels and Dimensions

The levels of the ground and the levels and dimensions of existing features shown on the Drawings are believed, but are not guaranteed, to be correct.

Wherever dimensions or levels are marked on the Drawings such dimensions or levels shall take precedence over dimensions scaled from the Drawings. Where no dimensions or levels are shown on the Drawings, instructions shall be obtained from the Engineer.

In the event of discrepancies between the Drawings and the Specification, the Contractor should ask to the Employer and Engineer. The Contractor shall be responsible for all setting out of the works in accordance with the drawings and the Engineer's instructions. On completion of any setting out he shall inform the Engineer who shall, if he considers it necessary, check all such setting out. No work shall commence until the Engineer has approved the setting out, but such approval shall not relieve the Contractor of any of his responsibilities or obligations under the contract.

Where directed by the Engineer, the Contractor shall take such levels and dimensions as may be required prior to the disturbance of the ground for the purpose of measurement. These levels and dimensions shall be agreed in writing before any of the surface is disturbed or covered up.

1.1.12 Closing of Roads

The Contractor shall not close any road unless the Authority having charge of the road surfaces has previously given the appropriate notice or order and without the Contractor having first obtained the written consent of the Police and of the said Authority to close the road. In the event of such consent being refused, the Contractor shall have no claim for any additional payment. In the event of such consent being given, the Contractor shall announce in advance the date of the commencement of the road closure to all statutory local or other authorities, public service undertakers and the public as may be affected by such closure and shall provide fix and maintain all warning signs and diversion notices as may be required by the said Authority by the Police and by the Engineer.

1.1.13 Traffic Restrictions

The Contractor shall not run tracked vehicles or tracked Equipment on any public or private road without the written approval of the Engineer and of the responsible authority or owner, and subject to such conditions as each may reasonably require.

The Contractor shall observe all weight and dimensions restrictions which apply to roads and tracks in Malawi and he shall comply with all reasonable restrictions which may from time to time be imposed by the Engineer, Employer, Police, responsible authority or owner. Where damage to roads and tracks is caused by the Contractor this shall be repaired at the Contractor's expense. In particular the Contractor shall fill potholes in roads with roadstone when these are deepened by his Equipment.

The Engineer shall have the power to restrict the Contractor's use of any roads, or tracks in terms of direction of traffic, speed of traffic, numbers of vehicles or their axle loading in order to preserve such roads or to make them safe for use by the general public.

Where other contractors require the use of these roads or tracks, the Engineer may prescribe times of usage, or impose some other form of control, which shall be established and operated by the Contractor, including the supply of traffic lights, flagmen, traffic cones ordrums, and other controls.

1.1.14 Flagging, Lighting, Watching and Traffic Control

The Contractor shall be responsible for watching and lighting the Works and for the flagging and control of traffic and he shall comply with the requirements of the Employer and Police and the relevant authority in these matters.

1.1.15 Circulation on the construction site

The Contractor shall make provisions to ensure, during the execution of the works, the maintenance of the pedestrian and vehicle traffic on the permanent roads crossing the construction zones which are the object of this tender. All the site and roads are to be permanently watered (wetted) in order to avoid dust.

The contractor shall execute temporary works and deviations necessary; he shall ensure the indications during the day and night as well as maintain security guards imposed by the regulation in force.

1.1.16 Borrow Zones and Deposit

If according to the guidelines of the Engineer, borrow pits of materials for the realization of the embankments, backfilling, filling works etc. are needed, these shall be specified by the Contractor. They shall then be placed freely at his disposal by the Administration. The Contractor shall make sure that the borrow pits staked out, shall allow him to extract volumes of materials necessary, all this material reconnaissance being under his charge. For that he will conduct all the necessary additional geological and geotechnical surveys required following the instructions of the Engineer. The provisional and final points of discharge necessary to the realization of the works shall be defined by the Contractor in a plan of movement of the Earthworks and subjected to the approval of the Engineer. The provisional discharge points shall necessarily be near the zones of application.

At completion and before reception of the works:

- The provisional work areas shall be cleaned.
- The final working areas shall be replaced according to instructions of the Engineer.
- The borrow zones shall be refilled using materials not re-used in fill and to be re-applied according to the instructions of the Engineer.
- The borrow pits are to be, as far as possible, refilled using materials different from what has been used in backfilling and it is to be spread according to the instructions of the Engineer. The Contractor will plant soil protection shrubs like penissetum and will provide infiltration trenches according to required spacing. All the borrow pits or disturbed areas are to be properly managed by the Contractor till the final hand over of works.

1.1.17 Origin and quality of materials, products and workmanship

The supply and the storage of all materials necessary for the works shall be the responsibility of the Contractor and shall be carried out under his sole responsibility. All goods and materials to be provided by the Contractor and incorporated in the Works shall be new, unused, and of the most recent or current design. The materials shall satisfy the standards set down by the present particular specifications. However, the products corresponding to other current standards of qualities equal or higher than those of the standards required could also be accepted. These products and standards shall undergo a preliminary approval by the Engineer.

All the materials, matters and products incorporated in the works shall be of quality and shall come from quarries or factories approved by the Engineer. Those whose origin and trademark shall not be defined shall be proposed to the Engineer who shall before deciding, require, in addition to the production of a documentation and references, samples and carrying out of control and quality tests. All the tests and controls of materials shall be carried out by an approved laboratory, at the expense of the Contractor. The Contractor shall not in any case ask for an unspecified increase in price of the works from suppliers or subcontractors without consultation from the Engineer.

Before any ordering of material, the Contractor will have to subject to the agreement of the Engineer the identity of manufacturers and the properties of the materials which he intends to order. With this intention, he will submit to the engineer all the appropriate documentation as well as the guarantees offered.

Generally, the materials and workmanships shall satisfy the standards and norms as defined in the present Technical Specifications and shall be approved by the Engineer. In the reading of the Specifications the words to the approval of the Engineer shall be deemed to be included in the description of all operations for the due execution of the Works.

Should any materials or manufactured articles be brought on to the Site which, in the judgement of the Engineer, are unsound or of inferior quality or in any way are unsuited for the work in which it is proposed to employ them, such materials or manufactured articles shall not be used upon the Works but shall be branded, if in the opinion of the Engineer this is necessary, and shall forthwith be removed from the Site.

The Contractor shall be responsible for his own quality control and shall provide sufficient competent personnel on the Site for taking and preparing samples and for carrying out the necessary tests.

1.1.18 Tests and control of materials, matters and products

The Engineer has the outright control over quarries, stores and construction sites of the Contractor and those of his subcontractors on the preparation as well as on the utilisation of the materials, matters and products forming part of the works. Controls do not reduce anything to the responsibility of the Contractor as far as good quality of the materials, matters and products to be used are concerned.

Samples of all natures, in quantities sufficient for the tests, shall be provided freely by the Contractor to the Engineer or to his representative at his request. The control tests or reception of materials by the Engineer or on his request will be at the cost of the Contractor. The minimum number of material tests is defined in the Specifications or by the Engineer.

1.1.19 Bad Weather

Following bad weather preventing the continuation of the works, and at the written request of the Contractor, the Engineer can authorize stoppage of the works. At the stoppage or suspension of the works, the Contractor shall then make note to the Engineer the impossibility in which it is to continue his activities. Recommencement of the works shall also be by written notice to the Engineer.

1.2 THE SITE

1.2.1 Site Preparation

(a) General

Except where otherwise shown on the drawings or specified herein, the Site shall mean the extent of such public and private lands as is in the opinion of the Engineer necessary or practicable for the construction of the Works. The Contractor shall not use the Site for any purpose not required by the Contract.

(b) Access to Site

Prior to the commencement of any part of the Works, the Contractor shall make temporary access tracks including all necessary temporary diversions and bridge works to the part of the Site concerned, all to the approval of the Engineer.

The Contractor shall maintain such access tracks in a condition suitable for the safe and easy passage of plant and vehicles until they are no longer required for the purpose of the Contract.

The Contractor shall keep such surfaces in a reasonable state of cleanliness and repair during the execution of the Works. On the termination of the Contractor's use of such access he shall restore the surfaces to a condition at least equal to that obtaining before his entry on them.

For the purpose of this Contract, all road tracks, which are not part of the permanent Works, but are required in connection with the Works under the Contract, will be called Construction Roads. These roads will be regarded as Temporary Works.

The Contractor is not entitled to any reimbursement for the use of the Construction Roads by others than the Employer, personnel and agents of the Engineer and the Contractor, provided that they use it with the approval of the Engineer and directly or indirectly in connection with the Works under the Contract.

The Contractor shall erect and maintain along the site boundary at his own expense suitable and approved temporary fencing and gates to enclose areas of the Works to be carried out and other areas of land as may be necessary to implement his obligations under the Contract to the satisfaction of the Engineer.

(c) Prevention of Surface Erosion

The Contractor shall take particular care at all times to prevent surface erosion on the Site and elsewhere on land which may be affected by his operations and the Engineer may impose such reasonable limitations and restrictions upon the method of clearance and upon the timing and season of the year when clearance is carried out as the circumstances seem to him to warrant.

1.2.2 Site Investigations

The Contractor shall carry out his own investigations at his own expense to draw his own conclusions, particularly in regard to the level of rock, soil type etc. He may if he wishes, subject to the approval of the Engineer, make further explorations at his own expense in order to ensure himself of the adequacy of design of structures.

The Engineer may direct the Contractor to execute further investigations and the Contractor shall be responsible for immediate execution of such works. The effects of any delays caused by the Contractor not executing such instructions promptly will be to his own account.

Prior to carrying out any work the Contractor shall inspect the Site, in conjunction with the Engineer or his Representative to establish its general condition which shall be agreed and recorded in writing, and where, in the opinion of the Engineer or his Representative it is deemed necessary, by means of photography or video recording.

These locations include:

- Contractor's site offices
- Workshop areas
- Routing of construction roads

Details recorded shall include the location of all boundary and survey beacons the conditions of buildings, surfaces, terracing (if any), ditches, roads, tracks, fences, and other information relating to the Site and elsewhere which may be affected by the Contractor's operations.

1.2.3 Contractor’s Yards, Stores and Accommodation for Workmen

The Contractor shall make his own arrangements for all land, yards, stores, workshops, offices, etc. required by him for the purposes of the Contract, and for all services in connection therewith.

The locations of all yards, stores, workshops, offices, etc., shall be agreed beforehand with the Engineer and shall be such as to minimize obstruction and nuisance to the public. In particular, the Contractor shall demonstrate that he will take such measures as are necessary to prevent pollution of the environment from fuel and oil spillages, washing of concrete mixers and the like.

The Contractor shall provide and maintain suitable and sufficient shelters and mess rooms for his workmen and supervisory staff as are customary and necessary.

The Contractor shall provide sufficient closets or latrines to the satisfaction of the relevant authority for the use of his personnel. They shall be properly screened and maintained in a clean and sanitary state at all times.

The mess rooms, closets and latrines shall be located in positions to be approved by the Engineer. The Contractor shall be responsible for making all arrangements for the disposal of waste from mess rooms, closets and latrines.

1.2.4 Site for Additional Accommodation

In the event of the Contractor making use of any special or temporary way leave or additional accommodation acquired by him pursuant to the Conditions of Contract hereof or any tip for the disposal of surplus materials, he shall obtain and forward to the Engineer a copy of the written consent of the owner and occupier or Authority having charge of the land in which such way leave accommodation or tip is situated and shall make a record to be agreed by the Engineer of the condition of the surfaces of that land before entering thereon. The Contractor will not be permitted to occupy space in public roads or thorough fares along the route of pipelines nor additional accommodation except with the written consent of the Engineer, which consent will not be given unless the Contractor shall have first obtained the written consent of the Authority concerned and having charge of the road surface.

1.2.5 Security of the Works

Watching of the works shall be provided by the Contractor at his own expense. If the Engineer considers it necessary he will order in writing that additional watchmen be provided, all at the Contractor’s expense.

The Contractor shall provide to the works an adequately supported temporary screen or fence in accordance with local by-laws and to the approval of the Engineer.

All excavation shall be adequately lit at night complete with hazard warning lights to pedestrians and traffic in accordance with applicable Traffic Police Regulations.

Unfenced openings and surface obstructions shall be attended by day and night and shall be adequately lit at night.

1.2.6 Precautions Against Contamination of the Works and the Environment

The Contractor shall satisfy the Engineer that all his personnel working on the Site are medically fit to be in contact with public water supply and his personnel shall undergo any necessary medical tests to show that they are free from any infectious diseases and are not carriers of any such diseases. The Employer reserves the right to call for medical certificates in respect of any employee of the Contractor.

The Contractor shall take all necessary precautions to secure the efficient protection of all waterways against pollution including spillage of oil or concrete mixer wastes, site drainage or any other harmful materials. The Contractor shall seek the Engineer's approval before discharging any substance that may degrade groundwater quality. If nevertheless, such spillage occurs, the Contractor shall clean the waterway at his own expense, and keep the Employer indemnified against any claim arising from such pollution during the execution of the works and the Defects Liability Period.

The Contractor shall be responsible for making all arrangements for the disposal of water from the testing and sterilising of pipelines, water retaining structures and treatment works.

1.2.7 Cleaning of Site

The Contractor shall take particular care and all reasonable precautions to ensure that roads and thorough fares used by him, either for the construction of the works or for the transport of plant, labour and material, are not made dirty as a result of such construction or transport and shall take all necessary and immediate steps to clean them when required or instructed by the Engineer.

Each individual site must be kept clean during the work and must be thoroughly cleaned up on completion.

The Contractor shall control the accumulation of waste materials and rubbish and periodically dispose of legally at an off-site location. All interior surfaces shall be cleaned prior to starting finish work. All areas shall be maintained free of dust and other contaminants during finishing operations.

All trash, debris, unused materials and temporary facilities shall have been removed from the Site. Tools, equipment and construction machinery not needed during the subsequent Defects Liability Period for repair and adjustment shall not remain on the Site. The temporary walkways, parking areas and roadways shall be completely swept and broomed.

1.2.8 Temporary Water and Electricity Supplies

(a) Water

The Contractor shall make all necessary arrangements for and shall provide at each Site an adequate supply of water both for the execution of the Works and for the health and safety of his workmen and other persons legitimately on the Works.

The water for the execution of the Works shall be of a chemical and purity standard such that it will not pollute injure or cause any deterioration of the Works, and it shall generally comply with the requirements specified in that section of the Specification dealing with concrete.

(b) Electricity

The Contractor shall make all necessary arrangements for and shall provide any electricity supply required for the execution of the Works. Should the Contractor use a generator, he shall minimize nuisance from noise or exhaust fumes and shall effectively guard against contamination or danger due to spillages of fuel or exposure to vapour.

1.2.9 Supplies Power, Water, Sewerage, Drainage, Sanitary Provisions

Where required by the Engineer, at or near the site, including all the facilities, the Contractor at his expense shall arrange for, provide, install and construct everything necessary to adequately ensure:

(a) the supply of potable or non-potable water, whichever is required, for construction, testing and domestic use and all other purposes;

(b) the supply of electricity and other sources of power and light;

(c) the drainage and the disposal of sewage;

(d) the drainage of surface and storm-water.

1.2.10 Contractor's Temporary Works

The Contractor shall design at his own expense all Temporary Works he may require for the execution of the Works. He shall submit six (6) weeks in advance of any scheduled temporary work, detailed drawings and supporting calculations considered essential by the Engineer.

Within four weeks after submission of the aforementioned drawings and calculations the Engineer shall comment or approve the relevant Temporary Works.

Notwithstanding the approval by the Engineer of any design of Temporary Works, the Contractor shall remain responsible for their efficiency, safety and maintenance, and for all obligations in regard to such works specified or implied in the Contract until the removal of such works.

Unless provided for in the Bill of Quantities expenditures whatsoever dealing with any Temporary Works shall be deemed to be covered by the other rates and prices in the Bill of Quantities and shall not be measured for payment nor be paid for under a separate item.

1.2.11 Existing Services and Installations

The Contractor shall take every precaution to ensure that all existing services, pipes, culverts, cables, boundary walls and fences, retaining walls, drainage and irrigation ditches and the like, within and near the line of excavation, are located, supported and safeguarded from damage. Any damage caused to any such services, pipes, culverts, cables, boundary walls and fences, retaining walls, drainage and irrigation ditches and the like attributable to the Contractor's operations, his constructional traffic or his negligence shall be made good by or for the Contractor at his own expense to the satisfaction of the Engineer, owner or responsible authority.

1.2.12 Temporary Removal of Existing Services

If it should become necessary for the proper execution of the work temporarily to remove or divert any existing pipe, sewer, field drain, cable, drainage or irrigation ditch or other service, the Contractor shall obtain permission from the responsible authority or owner and shall carry out the work at his own expense in a manner and at times to be approved by such authority or owner and shall subsequently reinstate the work to the satisfaction of such authority or owner.

In the event of the owner or responsible authority electing to arrange for the temporary removal of an existing service, the Contractor shall pay the cost of his or their doing the work. Should the Contractor fail to pay the cost of the said work within one month of the account being presented, the Employer reserves the right to settle the account and deduct the sum paid by him from monies due or which may become due to the Contractor.

The Contractor's attention is particularly drawn to the requirement to maintain drainage and irrigation ditches in order to avoid any interruption of flow of water therein to the satisfaction of the Engineer, owner or responsible authority and the Contractor shall be deemed to have included in his rates and prices for all temporary works so required.

1.2.13 Boundaries of Works

The Employer will provide land on which the Permanent Works included in the Contract are to be constructed. Where a drain or pipeline is to be within an existing road reservation the Contractor's working width may be restricted. The existing boundary fences and walls shall not be disturbed without the prior approval of the Engineer and the carriageway shall be left available to traffic.

The Contractor shall not enter upon or occupy with men, tools, equipment and materials any land other than land or rights of way provided by the Employer without the written consent of the owner of such land.

The Contractor shall provide temporary fencing, or immediately install permanent fencing where such is required. Where the Permanent Works do not include fencing (drains and pipelines etc.) the Contractor shall submit proposals to the Engineer for fulfilling his obligations under the Contract, and shall obtain the approval of the Engineer.

1.2.14 Demolition of Contractor's Temporary Works

The Engineer may at any time before the end of the Defects Liability Period give the Contractor notice in writing to demolish and remove those Temporary Works which are no longer required, whereupon the title to such Temporary Works shall revert to the Contractor. After the demolition and removal of the Temporary Works as required by the Engineer, the Contractor shall level, clear, restore and make good the sites and surrounding ground and fill in all latrines, drains, pits and similar items leaving the whole area in a neat and tidy condition to the satisfaction of the Engineer and any relevant authority.

1.2.15 Contractor's Compounds

An item is provided in the Bill of Quantities to cover the Contractor's costs of providing and maintaining the offices, compounds, workshop and housing necessary for the proper Organization and superintendence of the works. The Employer will provide the land required for the compounds.

The Contractor has to submit to the Engineer the layout and design of his compounds showing areas required for workshops, garages, concrete yards, stores, housing etc. for his approval.

The compounds and their contents shall be dismantled and cleared away by the Contractor upon completion of the Contract.

The Contractor shall provide, erect and maintain signboards at locations as directed by the Engineer. They shall be lettered in English and be not smaller than 3 m x 2 m in size. The wording shall be as directed by the Engineer.

1.2.16 Resident Engineer's Office

The Employer (and the Consultant) will establish his own Engineer's office in the project area. The Contractor shall provide office rent, furniture and equipment with the approval of the Engineer.

The Contractor shall obtain quotations for various office furniture and equipment to be purchased under this Contract and provide catalogues to enable the Engineer to make his selection of the equipment needed.

The Contractor shall also provide sufficient and regular supply of fresh water, stationery and consumables and other office requisites at his expenses as required by the Engineer and his staff.

1.2.17 Laboratory

The Contractor should provide the laboratory equipments which can check the items shown on below, also should provide the tables, chairs, and etc. The Contractor should report and should get the approval of specifications for the laboratory equipments and other materials mentioned above to the Employer before purchase and provide to the Employer.

Checking items:

- Concrete: Temperature, Mixing ratio, Strength, Workability, Aggregate particle size, etc.
- Soil: Soil layer exploration (Depth 2~3m, Hand auger, Ground water level, etc.), Particles (Gravel, Sand, Silt, Clay), Density, Atterberg (Liquid limit, Plastic limit), Moisture content, Permeability, Compaction level, Bearing Capacity (Plate bearing test equipment etc.), etc.
- Rock: : Strength, Dip/Strike (Clinometer etc.), Ripperability (rock hammer, etc.), etc.
- Water: Temperature, pH, Chloride, Sulphate, Salinity, etc.

1.2.18 Control of Construction Noise

The Contractor shall employ the best practical means to minimize noise and vibration produced by his operations. These shall include but not be limited to the following:

(a) All vehicles and mechanical plant shall be fitted with effective exhaust silencers and shall be maintained in good and efficient working order.

(b) All compressors shall be "sound reduced" models fitted with lined and sealed acoustic covers which shall be kept closed whenever the machines are in use, and all ancillary pneumatic percussion tools shall be fitted with mufflers or silencers. Dampened bits shall be fitted to percussion tools.

(c) Machines in intermittent use shall be turned off or throttled down when not in use.

(d) All mobile pumps shall be fitted with effective exhaust silencers where appropriate, and maintained in good and efficient working order. Pumps running overnight shall be effectively silenced. Alternatively the Contractor shall use electrically driven pumps if necessary.

(e) All stationary plant shall be screened where possible.

1.2.19 Noise Entry to Private Land

Where it is necessary to enter on privately owned land for the purpose of making temporary road diversions, or for any other reason, the Contractor shall consult the landowner or occupier and his written permission obtained.

The Contractor shall ensure that, in case the landowner or occupier refuses access, the Engineer is informed at least 6 weeks prior to the intended start of work in the area concerned.

Care shall be taken that no undue damage is caused to the land, and at the completion of the work, the land shall be left in a tidy and restored condition to the satisfaction of the landowner or occupier and the Engineer.

1.2.20 Safety Measures and Services

(a) The Contractor shall be responsible for the safety and health of all workmen and other persons in or around the works, to the satisfaction of the Engineer. Such measures shall include, but not be limited to the following:

(1) Provision of proper safety and emergency facilities and procedures; fire, gas and electric shock prevention, stretchers and first aid box together with rescue facilities generally at each place of work;

(2) Adequate supports and braces for all excavations;

(3) Provision of sufficient safety helmets for all staff including the Engineer, his staff, and any authorised visitor to the site;

(4) Safe control of water including the provision of standby plant;

(5) Provision and maintenance of safe, sound ropes, slings, pulleys and other lifting equipment, each having an up-to-date test certificate;

(6) Provision and maintenance of safe, sound mechanical frames, hoists, cranes, and vehicles for transporting materials and personnel, with an up-to-date test certificate for each item;

(7) Provision of good and safe access to the works;

(8) Provision of warning notices to the public in English, warning them of the existence of any dangers related to the works.

(b) The Contractor shall ensure that employees are available at each site to administer emergency first aid in (a) above, and that all employees are aware of their names. The Contractor shall provide for the transport of serious cases to hospital. All medical facilities shall also be to the satisfaction of the regional medical officer to inspect medical facilities at the Site.

(c) The Contractor shall ensure that all his employees are fully conversant with the regulations and emergency procedures, and shall enforce the rule that any employee committing a serious breach of such regulations shall be immediately dismissed from site and shall not be re-employed.

1.2.21 Sanitary Arrangements

The Contractor shall provide and maintain sufficient sanitary conveniences for all operatives and site staff engaged on the works. These shall be in accordance with any requirements and regulations of the Government of Malawi and subject to the approval of the Engineer. The location shall be thoroughly disinfected at the end of the Contract.

The Contractor shall ensure that all operatives and site staff are aware that the sanitary conveniences must be used by all personnel, and the Engineer reserves the right to require the dismissal of any person committing a nuisance on or about the site by failing to properly use the conveniences provided.

1.2.22 Training

The Employer may delegate to the Contractor a team of engineers and technicians to be trained on various sections of the works.

The Contractor shall submit upon request of the Engineer a training program and shall report to the Engineer in writing in monthly intervals detailing the activities and attendance.

The Contractor shall allow for free access to the site of authorized representatives of the sector organizations for inspection of the works upon given notice.

The Employer would be responsible for recruiting staff for the works. A minimum of six weeks prior to the introduction of the works the Contractor shall submit to the Engineer and Employer a training program indicating how he intends to train Employer's personnel in the operation of the Works. This should comprise but not be limited to:

- formal instruction in a 'classroom' type environment,
- formal 'hands-on' training on the works itself;
- attendance of Employer's personnel during pre-commissioning and setting to work;
- a short period of Contractor's support whilst Employer's personnel familiarize themselves with the operation of the works whilst under the Supervision of the Contractor.

1.2.23 Connection to Public Services

The Contractor shall be responsible to obtain in time all necessary approvals from the relevant Malawi Authorities to connect the works as described to the services provided by the Malawi

Authorities, and in such a manner as required and approved by these Authorities. The costs involved are deemed to be included in the Contract Price.

1.2.24 Telecommunications

The Contractor shall arrange for, provide, install construct and maintain adequate and sufficient means of telecommunication for the use of the principals, personnel and agents of the Employer, the Engineer and Contractor on or near the Site.

The Engineer shall be allowed free use of the Contractor's Communication facilities.

1.3 GENERAL REQUIREMENT OF WORK

1.3.1 Structural Design

The Contractor shall be responsible for the design of all reinforced concrete structures details and any other details related to connection to existing works or tie-in works.

1.3.2 Program of Performance and Methods of Construction

The Program of Performance shall include but not be limited to the following items:

(a) Proposed dates for starting and completing the construction of the various parts and stages of the Works.

(b) Proposed dates for procuring materials, mobilization of the main plant required to complete the Works.

(c) Proposed hours of Site works for Contractor's personnel.

(d) Proposed system of Contractor's access and work roads and Site plan.

The Contractor shall submit monthly progress reports with the number of copies for the required Program of Performance, which is discussed with the Employer and Engineer. This planning must include the implementation of all the agreements made with the authorities which are involved and responsible for traffic, transport and existing services like water supply, power, telephone, fire fighting, drainage and the followings :

(e) Charts and detailed descriptions of progress, including each stage of design, Contractor’s Documents, procurement, manufacture, delivery to Site, construction, erection, testing, commissioning and trial operation

(f) Photographs showing the status of manufacture and of progress on the Site

(g) For the manufacture of each main item of the Works and Materials, the name of the manufacturer manufacture location, percentage progress, and the actual or expected dates of:

(1) Commencement of manufacture,

(2) Contractor’s inspections

(3) Tests

(4) Shipment and arrival at the Site

(h) Details describing: number of each class of Contractor's Personnel and of each type of Contractor's Equipment on the Site

(i) Copies of quality assurance documents, test results and certificates of Materials

(j) Safety statistics, including details of any hazardous incidents and activities relating to environmental aspects and public relations

(k) Comparisons of actual and planned progress, with details of any events or circumstances which may jeopardise the completion in accordance with the Contract, and the measures being (or to be) adopted to overcome delays.

Any consent of the Employer to this planning will not exempt the Contractor of his responsibility to complete the Works within the time as agreed and stated in the Contract.

The Contractor shall take the initiative to inform the local authorities in due time about hisprogram. The Contractor shall attend coordination meetings between the Employer and other authorities and shall supply all relevant information and data in his possession.

The possible simultaneous construction of adjacent works under separate contracts may require the Contractor to adapt his planning to that of other Contractors. The Employer will inform the Contractor in due time about the conditions to be expected during the period of interference of work. Such adaptations as far as are required in the interest of and at the request of Employer shall not entitle the Contractor to additional payments.

For any operations that may result in a safety hazard (e.g. deep excavation, concrete casting of foundation etc.), the Contractor shall submit in writing the method statements for such operations for approval by the Engineer not less than 30 days prior to the planned commencement of such work.

All materials to enable temporary connections and working arrangements to be made shall be provided by the Contractor.

The Contractor shall allow in his program a period of three weeks for the Engineer to check the details of the Works which the Contractor proposes to order, this period commencing from the receipt by the Engineer of complete information. No Works shall be manufactured or ordered from suppliers until the Engineer has signified approval of the Contractor's proposals.

At least 6 weeks prior to delivery of the Work, the Contractor shall submit to the Engineer for approval a full and detailed program for the erection and commissioning of the Work.

1.3.3 Contract Drawings

The Contract Drawings shall comprise:

(a) The Drawings listed in the Specifications.

(b) Any modifications to the Drawings approved in writing by the Engineer.

(c) Any drawings that are from time to time issued by the Engineer.

(d) Any drawings that are issued by the Contractor after approval by the Engineer.

(e) As-built Drawings that are produced either after or during construction.

1.3.4 Drawings and Documents

The Contractor will be requested to elaborate a Document Submission Schedule showing planned submission dates of Technical Documents and Drawings for approval/review by the Engineer. It will be subject to discussion with agreement of the Engineer. The main purpose will be to enable the Engineer to know in advance, how many drawings of which nature are to be expected when for the approval. This submission schedule will then be considered binding as long as the underlying version of the Program of Performance remains valid.

Subject to the requirements of these Specifications the Contractor shall prepare the detailed design and Working Drawings necessary to execute the works. The calculations and Working Drawings shall be submitted to the Engineer for approval prior to commencement of the relevant sections of the works on site.

The drawing format and deliverables of the design drawings and the document are as follows:

(a) Drawing Format

(1) Scaling of the drawings : 1/10,000~1/50,000 for general layout, 1/2,000 for the network plans, 1/100 vertical & 1/600 horizontal for profiles of pipeline

(2) Transmission main drawings : Plan and profiles on the same sheet

(3) Size : All drawings shall be on A3 size sheets

(4) Drawings : All drawings should be produced in digital format in DWG.

(5) Design Report : Description of design including calculations and results in tabular form bills of quantities and cost estimates

(6) Water Supply system : Tabular form of calculation results shall include 2 sections, outputs for pipes and nodes which shows pipe and node numbers, velocities, pressures and head losses

(7) General layout plans : 1/10,000~1/50,000 scale drawings

(8) Plans and Profiles : 1/2,000 scale for plans, 1/100 vertical scale & 1/600 horizontal scale for profiles

(9) Typical drawings : In proper scale, the drawings for trench cross-sections, house connections, valve chambers, fire hydrants, node details, manholes etc.

All documents shall be produced in English.

All dimensions in drawings, calculations and information furnished in connection with the Contract shall be expressed in metric SI units.

All drawings shall be sized to designations A1, A2, A3, and A4 unless otherwise specifically specified. Sizes A0 and above shall not be used. Each drawing shall carry the project title, the name of the Engineer, the Contractor and the Employer together with the drawing title and number and other relevant data, in the lower right-hand corner.

The Contractor shall submit his drawings and documents to the Engineer for review or approval at least thirty (30) days prior to the planned execution of the work concerned with the said drawings and documents. Manufacturing drawings for items to be fabricated outside the country shall be submitted within one hundred twenty (120) days prior to the planned start of manufacture.

The procedure for the submission, review and/or approval of drawings and documents shall be understood to be as follows; provided that the Engineer shall reserve the right to make any changes to such procedure during the course of the works when the Engineer deems necessary.

When the Contractor is ready to have the Engineer review and/or approve certain drawings and documents, he shall submit the number of clear copies which is made through discussion with the Employer and Engineer, readable copies of the drawings and documents within fourteen (14) days after receiving copies of the drawings and documents from the Contractor, the Engineer will return one copy with one of the following classifications:

(a) "APPROVED” (NO OBJECTION- stamp)

(b) "RESUBMIT AFTER CORRECTION"

(c) "REJECTED".

The Contractor may proceed with the work only upon receipt of drawings and documents which have been approved as shown in (a) above. Copies of all approved drawings shall be maintained at the Contractor's site office.

When returned drawings and documents have been marked as shown in (b) or (c) above the Contractor shall make necessary corrections and/or revisions to the drawings and documents in a timely manner and shall resubmit the number of copies which is made through discussion with the Employer and Engineer for revised drawings and documents until the submitted version is approved (NO-OBJECTION- stamp) by the Engineer.

Any work done prior to the approval of drawings and/or documents shall be at the Contractor's risk.

The Engineer's approval of the Contractor’s Technical Documents shall not relieve the Contractor of the obligation to meet all terms of the Specification and any of the plan which upon delivery to site is found to be incorrect or unsatisfactory, or which fails to perform its duty satisfactorily during commissioning or during the Defects Liability Period shall be replaced to the Engineer's satisfaction.

The Contractor shall be responsible for any discrepancies, errors, or omissions in the drawings and other particulars supplied by him, whether such drawings and particulars have been approved by the Engineer or not, provided that such discrepancies, errors, or omissions be not due to inaccurate information or particulars furnished in writing to the Contractor by the Employer or the Engineer.

The drawing format should be based on the existing designed drawing format.

1.3.5 Working Drawings

If required for the execution of this Contract or requested by the Engineer, the Contractor shall incorporate in the Contract Drawings all openings, ducts, recesses, anchor holes, etc. as required for the mechanical and electrical installations. All related costs are considered to be included in the Contract Price.

The title block shall be as on the Contract Drawings, and shall show in addition the Contractor's name and the descriptive name of the works shown on the drawing. Materials and material standards shall be indicated on the drawings.

Drawings from sub-contractors shall be checked signed and stamped by the Contractor before being forwarded to the Engineer, who shall deal in all respects exclusively with the Contractor.

When the Engineer has approved a working drawing, he shall return a copy marked "Approved" to the Contractor, who shall then insert the date of approval on the tracing and furnish the Engineer with three prints of the working drawings as approved.

Approval of a working drawing by the Engineer will only signify his general approval of the design and shall not make him liable for any error of the Contractor in detail or lack of strength or efficiency of any part. Where errors, deviations and/or omissions are discovered later, they shall be made good by the Contractor at his own expense irrespective of any approval by the Engineer.

1.3.6 Survey Records and As-Built Drawings

After clearing the Site, the Contractor shall take and record levels in the manner directed by and in the presence of the Engineer of the site and works. Such levels, when approved by the Engineer, shall be recorded by the Contractor on drawings and/or schedules, which shall be signed as a true record by the Contractor and the Engineer and shall form the basis of the measurement of the Contractor's work.

Excavation works shall not commence before the Engineer certifies such records.

Before the issue of the Completion Certificate the Contractor shall prepare As-built drawings of all works and installations under the Contract and submit them to the Engineer for approval. All as-built drawings should be provided by a number of copies and format which are made through discussion with the Employer and contractor and the Engineer.

1.3.7 Record Drawings

Within 4 weeks of the commencement of the Defects Liability Period, the Contractor shall deliver to the Engineer one complete set of record drawings of all works constructed under the Contract. The Engineer shall comment on the draft Record Drawings and within a further 8 weeks the Contractor shall then produce a definitive set in dynamic form which shall be delivered to the Engineer complete with the number of copies that is discussed with the Employer and Engineer.

1.3.8 Working Hours

The Contractor shall perform his construction work only during working hours on construction sites according to the labour law being currently in force in Malawi; (at present: total of 40 hours, distributed over 5 days per week, except on holidays).

In case the Contractor wishes to carry out works outside normal working hours or on Sundays and public holidays, he shall comply with Sub-clause of Conditions of Contract referring to such item.

Work during the Defects Liability Period shall be carried out only after the Contractor has given the Engineer at least 48 hours notice in writing.

1.3.9 Labour and Plant Returns

The Contractor shall include with his monthly reports details of all plant (including their values) and labour force employed on site together with a description of their deployment. The names and trade of hired labourers being local residents are to be shown separately. The Contractor shall also provide a list of all materials intended for use in the permanent works delivered to site.

1.3.10 Photographic Records

The Contractor shall provide photographic records of the execution of the works by having photographs taken at monthly intervals from such points as the Engineer may specify from time to time. The number of such photographs shall be discussed with the Employer and Engineer.

The Contractor shall supply the number of print sets, which is discussed with the Employer and Engineer, including date and description of works to the Engineer.

1.3.11 Photographs

The Contractor shall supply, each month, negatives and four copies of progress photographs, suitably inscribed, of a size not less than 250 mm by 200 mm of such portions of the Works, in progress and completed, as may be directed by the Engineer. The negatives and prints shall not be retouched. The negatives of the photographs shall be the property of the Employer and no prints from these negatives may be supplied to any person or persons without the authority of the Employer or the Engineer. The Contractor shall also provide photograph albums and mounts for mounting photographs.

1.3.12 Setting Out

The Contractor shall submit to the Engineer, both the general and detailed methods of complete setting out of the alignments of the various structures, etc. and the calculations for curvatures and the various setting out dimensions there by obtained from the position of the Works. At all times the Contractor shall give the Engineer notice sufficiently in advance but not less than 24 hours of his intention to set out.

The method of surveying shall be to the approval of the Engineer. Field books and tabulated data shall be well maintained and made available for inspection and checking by the Engineer upon request.

1.3.13 Joint Measurement of Works

In the event of the Contractor having to execute any work or provide any material with regard to which he intends to claim extras, or where works are to be covered up, he shall make arrangements to take measurements of the said works or material and shall inform the Engineer accordingly, giving a minimum of 48 hours notice. The Engineer will then join the Contractor for a joint survey. If these measurements are not taken jointly and recorded before the work will be executed, the Contractor's measurement will not be recognized by the Engineer.

The fact that such joint measurements have been made will in no way bind the Engineer to recognize the claim. The Engineer shall at all times have access to the Contractor's diary and may daily check the progress of relevant works, but this shall in no way bind the Engineer to accept the claim nor the value of the work other than by joint measurement.

1.3.14 Works Diary

The Engineer will keep a diary on the Site in which all his remarks, instructions, decisions and the essential details of the Works shall be recorded. The Contractor shall assist in keeping the diary by supplying daily any information on the Works requested by the Engineer.

If required by the Engineer, the Contractor shall read the diary within two days of each daily entry being made and shall sign each entry as having been read by him. The Engineer shall also sign the diary and hand a copy of the signed diary to the Contractor.

If the Contractor does not agree with the diary written by the Engineer in either accuracy or completeness, he shall record his remarks in the space provided therein before signing the diary as having been read by him or shall detail his disagreement in writing to the Engineer not more than seven days after having read and signed the diary. Otherwise he shall be considered to be in agreement with the contents of the diary; however the facts stated therein shall not be by themselves be a ground for any claim for payment under the Contract.

1.3.15 Instructions to be Recorded

The Contractor shall provide and keep permanently on the Site book, which is discussed with the Employer and Engineer regarding required number of copies, wherein the Contractor shall record all instructions relating to concrete work issued by the Engineer. One copy of every entry therin shall be sent to the Engineer on the same day as the entry is made.

1.3.16 Approval of Contractor’s Proposals

The Contractor shall supply to the Engineer the number of copies of the following documentation, which is discussed with the Employer and Engineer, giving details of his proposals for approval, within 4 weeks of the Contract Start Date.

(a) Design and working drawings and data including calculation and erection information.

(b) All technical specifications of all plant and equipment proposed for the works.

(c) Details of dead and live loads imposed by each item of plant on its foundations.

1.4 MATERIALS

1.4.1 Copies of Orders

The Contractor shall provide the Engineer with the number of copies for all orders, which is discussed with the Employer and Engineer, regarding the supply of materials and goods required for the works.

1.4.2 Samples

In addition to specific provisions in the specifications for sampling and testing of materials, the Contractor shall submit to the Engineer, as he may require, samples of all materials, which he proposes to use in the works. When approved, these will be retained by the Engineer.

Samples to be submitted shall be accompanied by an approved form on which all information about specifications, description, location of use, manufacturer etc. is stated.

The Contractor shall submit a “Materials Procurement Program” for all materials and equipment which are deemed to be used in the permanent works indicating dates for sampling, approval, ordering, delivery to site.

The Engineer may reject any materials or goods, which in his opinion are inferior to the samples submitted.

The Engineer's approval of manufacturers or material for the works, whenever required by the specifications, shall not relieve the Contractor of his responsibilities under the Contract.

1.4.3 Testing and Inspection

The Contractor shall provide the number of copies, which is discussed by the Employer and Engineer, regarding a test plan for both the factory and site tests and inspections, for the Engineer's approval. The plan shall consist of a logical step-by-step schedule indicating step, action and reaction. The plan shall be cross referenced to relevant sections of the Specification, Bill of Quantities, and British Standards (or equivalent where applicable), and shall state clearly the test method to be employed, the equipment to be used, the parameters to be measured, and the expected results. On satisfactory completion of the tests etc. the plan shall be completed with the results achieved and shall be retained for record purposes.

As and when the Engineer is satisfied that any plant is in accordance with the Specification and has passed the prescribed workshop tests, he will notify the Contractor in writing to that effect.

If after inspection or tests the Engineer decides that the plant concerned or any part thereof is defective or is not in accordance with the Contract, he may reject it by giving to the Contractor, within a reasonable time, notice in writing of his decision and the grounds upon which it is based.

(a) Tests

(1) The Engineer may examine and may require testing of any materials or goods to be used in the works at any place inside of Malawi. The Contractor shall give the Engineer unrestricted access to his, his sub-contractors' and suppliers' premises for such purposes at all times.

(2) The Contractor shall afford the Engineer all facilities, assistance, labour and appliances necessary for the convenient examination, testing, weighing or analysis of all materials and goods. The Contractor shall prepare all test samples the Engineer may require.

(3) Tests carried out off the site shall not relieve the Contractor of the responsibility of ensuring that the materials pass any required tests on site and when they are incorporated in the permanent works.

(4) The costs for all tests as prescribed in the Specifications and as directed by the Engineer

are to be borne by the Contractor and are deemed to be included in his contract prices.

(b) Test Certificates

(1) The Contractor shall obtain test certificates from his suppliers and forward the number of copies, which is discussed with the Employer and Engineer, regarding such certificates to the Engineer. Such certificates shall certify that the materials or goods have been tested in accordance with the specifications and BS, DIN, KS, and/or ISO standards, and shall give the results of the tests, which have been carried out. With regard to major project equipment, the Contractor shall ensure that the tests are carried out in the presence of the Employer's representative. For this contract, major equipment includes the following:

- Pumps, motors and their control panels;
- Transformer and devices;
- Generators and their control panels.

In the case of the contractor wishes, the additional equipment might be tested

(2) The Contractor shall provide adequate means on site to identify the materials or goods with their respective test certificates.

1.4.4 Facilities for Engineer to Take Samples

The Contractor shall provide facilities for the Engineer to take samples for testing of any of the concrete or other materials to be incorporated in the Works. Such samples may be taken before or after incorporation into the Works or at any stage during construction at the discretion of the Engineer.

1.4.5 Quality of Materials and Workmanship

The materials and workmanship shall be the best of their respective kinds and to the approval of the Engineer. The words "to the approval of the Engineer" shall be deemed to be included in the description of all materials and workmanship for the due execution of the Works.

All materials to be used in the permanent works shall be new and of the required specifications. The workmanship shall be of the specified quality, all to the approval of the Engineer.

1.4.6 Approval of Suppliers of Materials

Before entering into any sub-contract for the supply of any materials or goods, the Contractor shall obtain the Engineer's approval in writing of the sub-contractor from whom he proposes to obtain such materials or goods. Should the Engineer at any time be dissatisfied with such materials or goods or with the methods of operation carried out at such sub-contractor's works or place of business, he shall be empowered to cancel his previously given approval of such sub-contractor and to specify any other supplier whom he may choose or to approve another sub-contractor for the supply of such materials or goods. The Contractor shall then obtain the said materials or goods from such other supplier and shall bear any additional cost thereof.

1.4.7 Quality Control

The Contractor shall be responsible for his own quality control and shall provide sufficient competent personnel for taking and preparing samples and for carrying out the necessary tests.

1.4.8 Guarding of Moving Machinery

All moving machinery shall be adequately guarded to prevent injury through accidental contact. In particular exposed shafting and couplings shall be protected with suitable guards except where they are in normally inaccessible positions.

1.4.9 Packing for Export

The Contractor shall be responsible for the proper packing, storage and crating and clear identification of all materials or Plant supplied by him or his Sub-contractors, prior to dispatch and shipment from its place of manufacture.

All materials shall be packed and marked in accordance with international standards for export from the country of manufacture. All wooden cases shall be proofed with suitable anti-termite solution. Straw or similar organic materials shall not be used for packing.

The materials shall be packed and protected against deterioration in such a manner as to be suitable for transport by sea and overland and for 12 months subsequent storage on site.

All materials liable to deterioration from water or moisture shall be packed in cases with waterproof lining.

All packages shall be clearly and conspicuously marked with the Contractor's identification mark and the Employer's reference mark.

1.4.10 Storage on Site

The Contractor shall construct on the Site a storage compound and storage building where he shall place at his own risk all electrical and mechanical parts, pipe jointing rings and other materials delivered to Site and awaiting erection which are not separately stored (for example at approved pipe stockpiling points). The compound shall be of sufficient size to accept all such parts delivered and awaiting erection.

The storage building shall be weatherproof and shall be of sufficient size to accommodate all items requiring covered storage.

1.4.11 Manufacturer’s Instructions and Recommendations

The Contractor shall keep on site a file copy and shall provide a copy to the Engineer of all Manufacturers' Instructions and Recommendations for handling, storage and use of all materials to be incorporated into the Works.

2. CIVIL WORKS

2.1 GENARAL REQUIREMENTS OF STRUCTURES

2.1.1 Excavation for Foundations of Structures

The Contractor shall give sufficient notice to the Engineer to enable him to examine foundations well in advance of concrete being placed and no placement shall occur until such inspection shall have been carried out and the formation approved.

If the formation has become weathered prior to the placing of concrete the Contractor shall remove the weathered material and replace it with concrete as directed by the Engineer.

If the Engineer so directs, a bottom layer of excavation of not less than 75 mm thickness shall be left undisturbed and subsequently taken out by hand immediately before concrete or other work is placed. Similarly, where concrete or other materials is to be placed in contact with the side face of an excavation the Contractor shall, if the Engineer so directs, leave undisturbed the last 75 mm thickness of the excavation to that face until it is taken out neatly to profile by hand immediately before the concrete is placed.

Areas of excavation which are to receive a layer of concrete blinding or drainage layer under structural concrete shall be covered with such blinding or layer immediately the excavation has been completed and inspected and approved by the Engineer.

All surfaces shall be free of oil, water, mud or any material which in the opinion of the Engineer is not desirable.

Excavations for foundations and for thrust and anchor blocks shall be to such depth as shown on the drawings or as the Engineer may direct and no concrete or other materials shall be placed until the formation has been examined and approved. Due notice shall be given to the Engineer to enable him to examine the formation well in advance.

2.1.2 Decision of Rock Materials for Excavation

The ground materials at the excavation site are divided into soil and rock according to the hardness of the constituent materials. According to the USDA standard, if the compressive strength is less than 0.60 Mpa, it is classified as Soil, and if it is larger than that, it is classified as Rock. Rock is classified into 7 types, from very soft rock (or hard, soil-like material) to extremely hard rock, depending on the compressive strength. (See the table below)

Table 4–3 Hardness and unconfined compressive strength of rock materials

Hardness category	Typical range in unconfined compressive strength (MPa)	Strength value selected (MPa)	Field test on sample	Field test on outcrop
Soil*	< 0.60		Use USCS classifications	
Very soft rock or hard, soil-like material	0.60–1.25		Scratched with fingernail. Slight indentation by light blow of point of geologic pick. Requires power tools for excavation. Peels with pocket knife.	
Soft rock	1.25–5.0		Permits denting by moderate pressure of the fingers. Handheld specimen crumbles under firm blows with point of geologic pick.	Easily deformable with finger pressure.
Moderately soft rock	5.0–12.5		Shallow indentations (1–3 mm) by firm blows with point of geologic pick. Peels with difficulty with pocket knife. Resists denting by the fingers, but can be abraded and pierced to a shallow depth by a pencil point. Crumbles by rubbing with fingers.	Crumbles by rubbing with fingers.
Moderately hard rock	12.5–50		Cannot be scraped or peeled with pocket knife. Intact handheld specimen breaks with single blow of geologic hammer. Can be distinctly scratched with 20d common steel nail. Resists a pencil point, but can be scratched and cut with a knife blade.	Unfractured outcrop crumbles under light hammer blows.
Hard rock	50–100		Handheld specimen requires more than one hammer blow to break it. Can be faintly scratched with 20d common steel nail. Resistant to abrasion or cutting by a knife blade, but can be easily dented or broken by light blows of a hammer.	Outcrop withstands a few firm blows before breaking.
Very hard rock	100–250		Specimen breaks only by repeated, heavy blows with geologic hammer. Cannot be scratched with 20d common steel nail.	Outcrop withstands a few heavy ringing hammer blows but will yield large fragments.
Extremely hard rock	> 250		Specimen can only be chipped, not broken by repeated, heavy blows of geologic hammer.	Outcrop resists heavy ringing hammer blows and yields, with difficulty, only dust and small fragments.

Method used to determine consistency or hardness (check one):
Field assessment: _____ Uniaxial lab test: _____ Other: __________ Rebound hammer (ASTM D5873): _____
* See NEH631.03 for consistency and density of soil materials. For very stiff soil, SPT N values = 15 to 30. For very soft rock or hard, soil-like material, SPT N values exceed 30 blows per foot.

(Reference: Chapter 4 Engineering Classification of Rock Materials, Part 631 Gelogy National Engineering Handbook, United States Department of Agriculture (USDA))

In the case of SVTP detailed design, the ground constituent materials were classified into three types for convenience: soil, weathered rock, and rock. The USDA criteria applied to these three material classifications are as follows.

SVTP	USDA	On-Site Judgment
Soil	Soil	Easy work performance with backhoe
Weathered Rock	Very Soft Rock, Soft Rock	Moderate work performance with backhoe or hammers
Rock	Moderately Soft Rock, Moderately Hard Rock, Hard Rock, Very Hard Rock, Extremely Hard Rock	Use of pneumatic tools or by using of explosives

2.1.3 Structures Liable to Flotation

Certain structures may be liable to float during the course of construction and it shall be the Contractor's responsibility to take all necessary precautions to prevent flotation.

Where continuous pumping is necessary to protect the work this shall be maintained at all times. Where flanged pipes are provided in the walls or base of the structure, and are intended for non-potable duty, they shall not be blanked-off until instructions are given by the Engineer to do so.

In the event of pump failure the works for non-potable duty shall be permitted to flood to prevent flotation. If as a result of this action, damage is sustained by recently-placed concrete to an extent which the Engineer considers to be detrimental to the Works, such concrete shall be removed and replaced at the Contractor's expense.

2.1.4 Acceptance Tests

The Contractor shall include in his rates for acceptance tests on completed structures as may be specified or directed by the Engineer. The Contractor shall include for all labour, materials, water and equipment for conducting the tests and for proving the performance of the completed structures.

Water excluding structures shall be watertight and shall prevent infiltration of ground or rain water. Leaks shall be made good to the satisfaction of the Engineer.

Water retaining structures shall be tested. All water retaining structures complete with electrical and mechanical plant installed in position shall be finally tested, before the issue of the Certificate of Completion, under conditions fully representative of operating practice.

All leaks or other faults in structures shall be made good and the repaired structure re-tested at the Contractor's cost.

2.1.5 Backfilling around Structures

Rectangular Structures: The walls of structures for water treatment, chambers and other structures may be designed as being supported by intermediate, ground floor or roof slabs or beams. Backfilling around or loading the walls of such structures shall not take place until the concrete of the supporting slabs or beams has been cured.

2.1.6 Slips, Falls, and Excess Excavation

The Contractor shall prevent slips and falls of material from the sides of the excavation and embankments.

In the event of slips or falls occurring in the excavations, and where excavations are made in excess of the dimensions of the Permanent Works, the voids so formed shall be filled by the Contractor. When such voids occur in rock and, in the opinion of the Engineer, may affect the stability of the ground for the support of the Works, or of the adjacent structures and services, the Contractor shall fill the void solid with selected excavated material placed and compacted to the approval of the Engineer. The Contractor shall make no charge for additional payment in respect of filling such voids.

2.1.7 Disposal of Excavated Material

The Contractor shall transport and dispose of all excavated material not required for the Works, frequently and regularly (at least once per day). The locations proposed by the Contractor for disposing or storing excavated materials, whether temporarily or permanently, shall be subject to the approval of the Engineer.

2.1.8 Forming Slopes, Embankments and Cuttings

The slopes of any banking shall be accurately an uniformly dressed off to slopes as directed by the Engineer.

The Engineer may order excavated material to be used in forming embankments or making up low ground. Only suitable material shall be used for such work.

2.1.9 Explosives and Blasting

The Contractor shall at all times take every possible precaution and comply with the Explosives Laws of Malawi and regulations relating to the handling, transportation, storage and use of explosives and shall at all times when engaged in blasting operations post sufficient warning flagmen to the full satisfaction of the Engineer.

The Contractor shall at all times make full liaison with and inform well in advance and obtain such supervision and permission as is required from the Police and all Government Authorities, public bodies and private parties whosoever concerned or affected by blasting operations.

Blasting shall only be carried out on those sections of the Works for which permission in writing shall have been given by the Engineer and shall be restricted to such hours and conditions as he may prescribe. Such permission shall not be withheld nor such hours and conditions imposed unreasonably. The Contractor should provide the appropriate trained personnel in order to perform the blasting and for this personnel should have the permission by the Engineer.

The greatest care shall be taken in the use of explosives, the charges being so placed and of such amount as in no way to weaken existing structures or the foundations or ground adjacent to the existing and proposed works. The Contractor shall take all necessary precautions to prevent loss, injury or accident to persons or property and shall be entirely liable for any accident or damage that may result from the use of explosives.

The Contractor shall submit to the Engineer for his approval details of the intended drilling patterns, depths of holes, the amounts of explosives at each location and the method or sequence of detonation that he proposes to use. The Engineer may find it desirable to direct the Contractor to use special methods to obtain sufficient, even and undamaged rock surfaces.

2.1.10 Drainage Layers in Embankments

Gravel for horizontal and vertical layers in embankments shall be hard, clean, washed aggregates of 20 mm nominal diameter.

Any horizontal layers of such drainage gravel shall be laid in one continuous operation on a clean formation and shall be compacted by a method approved by the Engineer.

Vertical gravel drainage layers behind walls shall be placed in lifts in advance to the fill to the embankments, being compacted in layers by the use of light rammers. It shall be kept free from mixing with the filling material by the use of boarding or the like placed between the two materials and raised as the work proceeds.

The Contractor shall include in his rates for sufficient thickness of drainage material to ensure that the minimum thickness at any place is not less than that shown on the drawings.

2.2 EARTH WORKS

2.2.1 Condition of Site

Before carrying out any work on the Site, the Site shall be inspected by the Contractor in conjunction with the Engineer to establish its general condition which shall be agreed and recorded in writing, and, where in the opinion of the Engineer it is deemed necessary, by means of photography.

Details recorded shall include the location of all boundary and survey beacons, the condition of buildings, surfaces, terracing (if any), ditches, watercourses, roads, tracks, fences and other information relating to the Site and elsewhere (including storage and stockpiling locations) which may be affected by the Contractor's operations.

2.2.2 Location of Existing Services

The location of any existing services shown on the drawings is approximate only and not necessarily complete. Before carrying out any demolition or excavation for construction purposes the Contractor shall accurately locate in both line and level all existing services within the Site whether indicated on the drawings or not, and furnish the Engineer with 3 copies of the relevant information immediately.

2.2.3 Site Clearance and Topsoil Removal

Site clearance shall be carried out over the areas to be occupied by the permanent Works before beginning excavation or other work, and shall include the clearance of all trees, stumps, bushes and other vegetation and the grubbing out of all roots and the removal of all boulders between 0.01 and 0.2 m^3 volume. The limits of the areas to be cleared shall be as indicated on the drawings or as will be defined by the Engineer.

Following the establishment of ground levels, the Contractor shall strip topsoil, where indicated on the drawings or as directed by the Engineer to a depth of up to 300 mm. The topsoil so removed shall be deemed to become the property of the Employer and shall be set aside for re-use or disposal as directed by the Engineer.

Topsoil is defined as the surface layer of soil which by its humus content supports vegetation. This layer of soil is unsuitable, due to weathering and vegetable content, as a formation to roads and concrete structures or as a backfill or bedding material. The presence, extent and depth of topsoil that needs removal shall be agreed with the Engineer.

Subject to the requirements of this clause and the Conditions of Contract, all other materials arising out of site clearance will be deemed to become the property of the Contractor, and shall be disposed by him off the Site, or on the site in a manner and place approved by the Engineer.

Where shown on the drawings or directed by the Engineer, trees shall be uprooted or cut down as near to the ground level as possible and all timber shall be deemed to become the property of the Employer. The Contractor shall cut and stack such timber as is salvable as directed by the Engineer.

Bushes, undergrowth, small trees, stumps and tree roots shall, where directed by the Engineer, be grubbed out, burnt and deposited off the site in dumps to be provided by the Contractor. All holes left by the stumps or roots shall be backfilled with suitable material in a manner approved by the Engineer.

The Engineer may require that individual trees, shrubs and hedges are to be preserved and the Contractor shall take all necessary precautions to prevent their damage.

In the case of wayleaves for sewers, pipelines and the like, the area to be cleared shall extend over the full width of the wayleave but the Contractor shall preserve as far as practicable all grass and other vegetation outside the limits of trenches and permanent works within the wayleave and shall not unnecessarily destroy crops or any vegetation whose removal would not be essential to his operations.

Before beginning clearance within any wayleave the Contractor shall give seven days written notice of his intention to the Engineer who will determine the extent and limits of such clearance having regard to the Contractor's requirements, the rate of Contract progress, the reasonable wishes of owners and occupiers, weather conditions and other factors which in the opinion of the Engineer may affect or be affected by the Contractor's proposals.

2.2.4 Erosion

The Contractor shall take particular care at all times to prevent erosion on every site and elsewhere on land which may be affected by his operations and the Engineer may impose such reasonable limitations and restrictions upon the method of clearance and upon the timing and season of the year when clearance is carried out as the circumstances warrant.

2.2.5 Ground Levels

Following the completion of Site clearance and before the commencement of any earthworks or demolition the sites shall be surveyed in conjunction with the Engineer to establish existing ground levels and these agreed ground levels shall form the basis for the calculation of quantities of any subsequent excavation and filling. These levels shall be taken before any topsoil is removed.

2.2.6 Trial Holes

The Contractor shall excavate refill and restore before commencement of any permanent works such trial holes as he may require for the location of existing underground services and obstructions.

2.2.7 Excavation General

Excavation shall be made in open cutting unless tunnelling or heading is specified or approved by the Engineer and shall be taken out as nearly as possible to exact dimensions and levels so that the minimum of infilling will afterwards be necessary.

It shall be the Contractor's responsibility at all times to ensure the stability and safety of excavations and the Contractor shall take all measures necessary to ensure that no collapse or subsidence occurs.

The sides of all excavations shall be kept true and shall where necessary be adequately supported by means of timber, steel or other type struts, walings, poling boards, sheeting bracing and the like. All supports shall be of sound design and construction and shall be sufficiently watertight to permit excavation, concreting and other work to be completed satisfactorily.

Excavations shall be kept free from water and it shall be the Contractor's responsibility to construct and maintain temporary diversion and drainage works and to carry out pumping and to take all measures necessary to comply with this requirement.

The Contractor shall not deposit excavated materials on public or private land except where directed by the Engineer in writing or with the consent in writing of the relevant authority or of the owner or responsible representative of the owner of such land and only then in those places and under such conditions as the relevant authority, owner or responsible representative may prescribe.

2.2.8 Excavation in Excess

If any part of any excavation is in error excavated deeper and/or wider than is required the extra depth and/or width shall be filled, at the Contractor's expense, with concrete or compacted granular or other approved fill to the original formation level and/or dimensions as the Engineer may require.

In pipe trenches where the pipe is not bedded on or surrounded with concrete, the excess excavation shall be filled with compacted granular material. Excess excavation in rock trenches shall be filled with concrete up to 150 mm below the pipe invert.

2.2.9 Excavated Materials Suitable for Re-Use

In so far as they may be suitable and comply with the Specification, materials arising from excavations may be used in the Works.

During excavation, the Contractor shall ensure that all material suitable for re-use and which he intends for re-use are kept separate and set aside and protected as necessary to prevent loss or deterioration.

The materials forming the surface and foundations of roads, road verges, tracks and footways shall when excavated, and if required for further use, be carefully separated. All hard materials shall be kept free from soil or other excavated materials.

In particular, during excavation of pipe trenches the Contractor shall ensure that all granular or other approved material suitable for filling around and over pipes shall be kept separate and reused for this purpose.

Paving slabs, bricks and similar surfaces shall be carefully removed and stacked. Prior to the commencement of excavation the number of badly broken and unsuitable paving slabs, bricks etc. on the line of the excavation shall be agreed with the Engineer.

In verges and other grass surfaces the grass and top soil shall be stripped and separately stacked.

2.2.10 Disposal of Surplus, Demolished or Excavated Materials

All surplus demolished or excavated materials shall be disposed to appropriate distance not exceeding 1 Km of by the Contractor to tips provided by the Contractor and approved by the Engineer.

The Contractor shall not sell any materials arising from excavation, demolitions and the like carried out on the site.

The Contractor shall not deposit excavated materials on public or private land except where directed by the Engineer in writing or with the consent in writing of the relevant authority, owner or responsible representative of the owner of such land and only then in those places and under such conditions as the relevant authority, owner or responsible representative may prescribe.

Surplus material may not be tipped on the site without the written permission of the Engineer. In the event of such permission being granted the Contractor shall observe all conditions attached thereto.

2.2.11 Backfilling of Excavations

All backfilling of excavations shall be thoroughly compacted in layers not exceeding 150 mm compacted thickness and by means which will not damage the Works.

Backfilling of excavations for reinforced concrete structures shall be with suitable material approved by the Engineer.

"Granular material" as backfill is defined as unconsolidated laterite, crushed stone, quarry dust, gravel, sand or similar in which the clay or silt content is not predominant. Topsoil shall not be classified as granular material.

2.2.12 Making Good Subsidence after Refilling

All refilling shall be thoroughly compacted by ramming and any subsidence due to consolidation shall be made up with extra compacted material.

Should subsidence occur after any surface reinstatement has been completed the surface reinstatement shall first be removed, the hollows made up, and then the surface reinstatement relaid.

Any subsidence that occurs adjacent to the Site of the Works which is attributable to the Contractor's activities shall be reinstated to the full satisfaction of the Engineer.

2.2.13 Removal of Timber from Excavations

Timber shall be removed from the excavations before or during the process of refilling except in so far as this removal of timber would be likely to cause damage to adjacent property, structures or structure foundations in which event the Contractor shall leave in the excavation such timbering as he considers necessary or as may be ordered by the Engineer to prevent damage, the proper repair of which the Contractor shall be solely responsible for in the event of any such damage occurring.

Timbering means any form of approved excavation support system or part thereof.

2.2.14 Reinstatement of Surfaces

All surfaces whether public or private which are affected by the Works shall be reinstated temporarily by the Contractor in the first instance and in due course when the ground has consolidated fully he shall reinstate the surfaces permanently.

The temporary reinstatement and maintenance and permanent reinstatement and maintenance of all surfaces of roads, tracks, paths, fields, verges and any other surfaces which have been affected by the operations of the Contractor shall be his sole liability and shall be carried out to the satisfaction of the Engineer and of the responsible authority or owner.

Temporary reinstatement shall be carried out immediately the trenches are refilled.

Permanent reinstatement shall not be carried out until the ground has consolidated completely and the Contractor shall inform the Engineer before carrying out this work. In the event of further settlement occurring after the completion of the permanent reinstatement the Contractor shall forthwith make good the reinstatement to the approval of the Engineer or responsible authority.

For the purposes of temporary and permanent reinstatement in bitumen and murram surfaced roads the surface width of trenches shall be increased by 150 mm on each side of the trench for a depth of 75 mm to provide a solid abutment for the surfacing material.

Reinstatement of murram surfaced roads shall consist of approved "as dug" material placed in one layer 250 mm thick thoroughly compacted by an approved roller and surface blinded with fine material so as to leave a tight closed even surface, all to the satisfaction of the Engineer.

Materials forming the surface and foundations of bitumen and murram surfaced roads, tracks and footpaths may, if they are approved by the Engineer be used by the Contractor in the temporary reinstatement of surfaces. The Contractor shall provide all additional materials necessary for the reinstatement. All materials shall form a surface similar to the adjoining surface. The surface shall be well compacted.

Temporary reinstatement of trenches in bitumen surfaced roads shall comprise a layer of compacted hardcore, of minimum thickness 150 mm, topped with a 75 mm layer of surface material taken from the original surface together with any additional material to form a satisfactory running surface. The surface shall be well rolled and sealed with a coat of approved cold applied bituminous emulsion, applied with an approved sprayer at the rate of approximately 2 liters/m^2. The emulsion shall be blinded immediately with quarry dust or sand approved and then rolled with an 8 tonne roller.

The quality and grade of bitumen shall be suitable for the climatic conditions of the area and shall otherwise conform to BS 434.

Permanent reinstatement of surfaced roads shall be carried out to the approval of the competent authority. In bitumen surfaced roads the top layer of the temporary reinstatement shall be removed to expose the compacted hardcore which shall be topped up and re-rolled as necessary.

Trenches in open ground shall be reinstated to the condition in which the ground was found before excavation was commenced. The final surface of the trench shall be flush with the surrounding ground.

In verges and other grass surfaces and after the refilling has been thoroughly consolidated the topsoil shall be relaid rolled and planted with grass as may be necessary and watered until the grass has become well established. Should the grass fail it shall be replanted as required until a satisfactory growth is obtained.

The Contractor shall take all necessary precautions to ensure that no toxic materials which may cause damage to vegetation or livestock or pollute streams or watercourses are used in any temporary or permanent reinstatement and shall indemnify the Employer against any claims arising out of the use of such materials.

If at any time any trench becomes dangerous the Engineer shall be at liberty to call on the Contractor to restore it to a proper condition immediately.

If the work or reinstatement as carried out by the Contractor is not to the satisfaction of the Engineer and/or the responsible authority and should the Contractor not remedy the defect forthwith any remedial work considered necessary may be undertaken by the Employer and/or the responsible authority at the Contractor's expense.

2.2.15 Forming Banks and Filled Areas

Banks and filled areas shall be made and built up to the levels, dimensions and shapes as shown on the drawings or as may be subsequently directed by the Engineer. Before any filling is started, the ground on which the fill is to be placed shall be stripped of all grass and topsoil and all roots, vegetable matter and other unsuitable substances removed.

The filling to be used in the embankments and filled areas shall be material selected by the Engineer from that arising from surplus excavation, the material being placed according to its nature as shall be directed, that is, coarse hard material may be placed at the bottom with the fine materials and/or soil placed at the top or at the surface.

The fill shall be placed in layers not exceeding 150 mm thick, each layer being thoroughly compacted by an approved roller to the satisfaction of the Engineer.

2.2.16 Restoration of Borrow Areas, Spoil Tips and Quarries

Any spoil tips, quarries or other borrow areas developed by the Contractor for the purpose of the Works shall be finished to safe and fair slopes to the approval of the Engineer.

Where directed by the Engineer these areas shall be resoiled and grassed over or otherwise seeded. Operation of such borrow areas and tips shall be in accordance with the rules and regulations of the appropriate authority responsible for them.

2.2.17 Top Soiling and Grassing

Where required surfaces shall be soiled with fine sifted soil or silt not less than 100 mm compacted thickness which shall be raked and brought to a fine tilth. The Contractor shall supply approved material for this purpose or use the material.

Surfaces required to be grassed shall be planted with approved local grass at a spacing of 200 mm x 200 mm. The grassed areas shall be replanted if the first or subsequent operation is unfruitful or if for any reason the grass is destroyed. Grassed areas shall be watered and attended until the grass has become well established.

The soiling and planting of the grass in slopes shall be carried out immediately the slope is formed and the grass shall be kept weeded and cut until the work is accepted at the time of the Certificate of Completion.

The Contractor shall supply attendance during the Defects Liability Period to ensure that all planted grass is kept weeded and cut, and if necessary watered.

2.2.18 Free Draining Fill

Free draining fill for use as backing to walls shall consist of sound hard stone or broken rock or concrete derived from demolition of structures. The particles shall be roughly cubiform and shall be between 75 mm and 25 mm in size. All smaller particles, dust, rubbish and organic matter shall be excluded.

2.2.19 The Procurement of Equipment at the Construction Site

The Contractor should procure and use the proper equipment for the excavation (soil and rock), transportation, and etc.

The contractor should make a procurement plan of equipment before starting construction and obtain approval from the construction supervisor.

The Contractor shall conform to the local legislation with regard to the means of routing on the site as well as their use on the public highways and roads that access the site.

2.2.20 Material

- General

The embankment material shall be judged in various items such as permeability and strength, but above all, it shall have an optimum grain size distribution.

The transition part between the impermeable part and the permeable part shall be filled with semi-permeable material to prevent accidents caused by sudden change of material.

The rock material shall be strong, less cracked, and more durable against water or climatic action. It shall have a specific gravity of 2.6 or more, a compressive strength of 70 MPa (700 kgf/cm2) or more, and a durability of 0.015% or less.

Random materials that may be deteriorated by weathering shall not be used in important parts of the dam.

When two materials with significantly different grading are adjacent to each other, the filter material installed in the middle shall not be removed, and the seepage water shall be safely drained.

Embankment material testing shall be conducted on the items specified in the construction specification, and the results shall be submitted to the construction supervisor (or supervisor) for approval. When requested by a construction supervisor (or supervisor), a material test shall be carried out immediately.

- Impervious zone

The hydraulic conductivity of the impervious zone shall be less than 1×10-5mm/s.

Impervious material shall be impermeable material with good grading of clay, sand, gravel, and shall not contain foreign substances such as roots of vegetation or large stone, and shall be approved by the construction supervisor.

In principle, when water is sprayed or dried to ensure optimum moisture content, it shall be carried out in the borrow pit, and the method shall be consulted with the construction supervisor.

The foundation of the impervious zone shall be a bedrock capable of blocking water. If not, take appropriate measures to ensure sufficient blocking water and stability against settlement. The foundation shall be excavated without extreme uneven and protrusion parts. Appropriate treatment shall be performed for the fault and relaxed layer in the foundation part.

- Stone material

The stone material shall have larger density, hardness and abrasion resistance and not be destroyed by water or freezing.

The stone material shall have a good particle size distribution with No. 200 sieve passing ratio of 3% or less.

- Slope protection

The riprap material shall be durable material that is not weathered and shall be rock with sufficient weight per piece that is not moved by wave power. Weight per piece, particle size, etc. of the stone shall be used after approval of the construction supervisor.

2.2.21 Material Test

The Contractor shall install and operate a laboratory for quality control of materials, soil and concrete related to the construction. What is needed in the laboratory includes not only test equipment, but also water supply, electricity supply, consumables, and reagents required for the test.

The Contractor shall also conduct a separate test if requested or directed by the construction supervisor (or supervisor) for construction management.

All quality control tests shall be performed in accordance with KS standards, test regulations, and specifications, and test results shall be submitted after the test.

The construction supervisor (or supervisor) may direct the test directly at the manufacturing plant or at the site when deemed necessary before the material is brought on-site. If the construction supervisor (or supervisor) approves, a test report prepared by a manufacturer or an authoritative testing laboratory may be submitted.

2.2.22 Construction Management Tests

For earthwork construction, it is necessary to measure water content and dry density of three random samples for each layer and many samples as necessary at the places where the construction condition seems poor. And, if necessary, the measurement of the pore water pressure generated in the dam body and the foundation ground, the shear test and permeability test of embankment shall be conducted and compared with the regular construction management test.

In dams built on soft ground, the relationship between the construction progress of embankment and the dissipation of pore water pressure or the increase of the ground strength shall be adjusted.

The dry density shall be within the allowable water content ratio and shall be more than the standard value.

The soil test for embankment is required for the optimum moisture content ofCs, selection of suitable compaction equipment, the number of compactions, spreading thickness, drying and spraying method of impervious materials, etc. If necessary, the storage method of earth materials shall be consulted with the construction supervisor (or supervisor).

When material or compaction equipment is changed, test embankment shall be conducted to determine the spreading thickness, number of compaction and optimum moisture content, and the results shall be submitted to the construction supervisor (or supervisor) for approval.

The number and timing of on-site quality control tests shall be in accordance with the construction specifications.

Test embankment shall be performed for 3 types of spreading thickness and 3 types of number of compaction , totalling 9 times for each, and for permeable and impermeable materials.

2.2.23 Tolerances of Embankment Construction

The construction tolerance range for the completed embankment section is as follows.

(a) The finished surface shall be within ±30mm for the embankment floor and ±50mm for the embankment body at the specified elevation.

(b) In the case of the finished surface of the embankment floor, when measuring with a 3m straight ruler parallel to or at right angles to the road centerline, there should not be any irregularities of more than 10mm. Measurement should be carried out by overlapping the straightedge in half or more where the measurement has already been completed.

(c) The slope of the embankment must be completed within ±50mm from the specified slope, and it must not invade the base layer or the embankment floor.

(d) The moisture content of the embankment material must be maintained within ±2% of the moisture content approved by the construction supervisor during installation.

2.3 CONCRETE WORKS

2.3.1 General

This specification covers reinforced structural concrete for use in building and structure, appurtenances, foundations of equipments.

2.3.2 Reference Standards

Reference Standards for concrete works shall follow the Design Standards and detail codes described in Sub-section 1.1.3. The following codes shall govern the concrete work: Building Code Requirements for Reinforced Concrete (ACI 318) of the latest edition, or approved equal. Other codes, specification, and recommendations referred to in this ACI 318 code shall be interpreted as part of that code.

2.3.3 Submissions of Report on Workability and Consistency of Mixtures

The Contractor shall report concerned on workability and consistency of the concrete mixture for approval of the engineer.

(a) Concrete shall be composed of portland cement, fine aggregate, coarse aggregate, and water. The Contractor may find that an admixture is required for retarding or accelerating the setting and improving the workability of the concrete; however, its use must be approved by the Engineer. These materials shall be combined in such proportions as will result in the specified strength and maximum density and water tightness.

(b) The relative proportions of these materials and the consistency of the mixture shall be at all times subject to the approval of the Engineer. Tests for strength and material requirements shall have been completed and approved before concrete is placed.

2.3.4 Materials

Not less than 90 days before the start of the concrete work at the site, the Contractor shall furnish the Engineer with a written report showing the source, producing company and intended use of the materials required in the work.

The report shall include a description of the proposed methods and the equipment to be used by the producer for the production of the materials and a description of the methods to be used to control and inspect the quality, uniformity, and cleanliness of the product. The source of supply and quality of each of the materials shall be approved by the Engineer and the Engineer's Representative before delivery is started.

(a) Portland cement shall comply with specification for portland cement, ASTM C150-89, Type I and Type III, or equal, with all brands subject to approval. Type III, for high early strength concrete, shall be at the Contractor's option but subject to the approval of the Engineer.

(b) Air entraining admixtures shall conform to ASTM C260, or equal. The Contractor shall furnish to the Engineer's Representative certification that the air-entraining agent has been tested in accordance with ASTM C233, or equal.

(c) Retarding admixtures shall conform to ASTM C494, Type B, or equal. The Contractor shall present to the Engineer test reports from an approved laboratory certifying that the proposed admixture, when used with the cement and aggregates to be used for the project produces satisfactory content, slump, and strength.

(d) Water reducing admixtures shall conform to ASTM C494, Type A, D, or E, or equal. The contractor shall present to the Engineer test reports by an approved laboratory certifying that the proposed admixture when used with the cement and aggregates to be used for the project, produces satisfactory concrete, having the desired properties with respect to time of set, water-reduction, slump, and strength.

(e) Pozzolans, including fly ash: Pozzolanic materials other than fly ash shall conform to ASTM C618, or equal. Fly ash shall conform to ASTM C618, or equal. The Contractor shall present to the Engineer test reports by an approved laboratory certifying that the proposed admixtures when used with the cement and aggregates to be used for the project, produce satisfactory concrete having the desired properties with respect to workability and plasticity, with no adverse reaction.

(f) General Admixtures: Their use shall be optional subject to written approval by the Engineer. Admixtures used in pre-stressed concrete or seawater exposed concrete shall be certified by the manufacturer to be used in a mix, the contractor shall furnish satisfactory to be free of chlorides. When more than one admixture, the admixtures shall be compatible to mix together with the cement and aggregates for the temperature in the worksite. The cost of admixtures proposed for use by the contractor, when allowed, shall be at no change in contract price, except if the Engineer shall require the use of admixtures.

(g) Water shall be clean and free from injurious amounts of oil, acid, alkaline, salts and organic matter, or other deleterious substances.

(h) Aggregate: Fine aggregate and coarse aggregate shall conform to the requirements of ASTM C33, or equal. The nominal maximum size of the aggregate shall not be larger than one-fifth of the narrowest dimension between sides of forms; one-third of the depth of slabs, nor three-fourths of the minimum clear spacing between reinforcing bars, whichever is least. Aggregate shall be graded in accordance with the requirements of ASTM C33, or equal. These limitations may be waved if, in the judgment of Engineer, workability and methods of consolidation are such that the concrete can be placed without honeycomb or voids.

(i) Reinforcement: Reinforcing steel shall be deformed-type hard grade and intermediate grade billet-steel conforming to BS 4449 “Carbon steel bars for the reinforcement of concrete" or equal. Welded wire fabric (mesh) shall conform to ASTM A185-85 for "Welded Steel Wire Fabric for Concrete Reinforcement", or equal.

(j) Curing Materials

- Curing paper shall conform to the requirements of ASTM C171, or equal.
- Polyethylene sheets shall conform to the requirements of ASTM C171, or equal.
- Cotton mats shall conform to the requirements of AASHO M73, or equal.
- Liquid curing compound shall conform to the requirements of ASTM C309, or equal. The clear liquid curing compound shall contain a fugitive dye of sufficient strength to render the film distinctly visible on the concrete for at least four hours but shall leave no permanent discoloration.

(k) Test Cylinder Molds: The Contractor shall furnish a sufficient quantity of re-usable test cylinder molds for adequate sampling.

(l) Floor hardener shall be a sodium silicate or other approved type liquid hardener. Surfaces that are to receive a hardener finish shall not be cured with a liquid curing compound.

2.3.5 Testing

The Contractor shall submit test reports to the Engineer.

No material shall be shipped from its place of manufacture before it has been inspected and approved, unless the Engineer has specifically authorized the inspection to be made elsewhere, or has waived the inspection. Materials shall not be used until approval has been received from the Engineer. Approval of the materials at the producing plant does not constitute a waiver of the Engineer and the Engineer's right of reexamination at the project site.

(a) Cement shall be sampled at the mill and at the site of the work or at the direction of the Engineer's Representative, and the method of sampling shall conform to that outlined in the ASTM C183-83 for "Sampling Hydraulic Cement" or equal. Test reports to establish compliance with the specifications for each type of cement shall be submitted.

(b) Aggregates shall be sampled at their source and at the site of the work when directed by the Engineer, and test reports to establish compliance with the specifications for each type of aggregate shall be submitted. Moisture content of fine aggregate on the site shall be determined daily before concrete mixing is commenced. The amount of water to be added to each batch shall be adjusted at the direction of the Engineer to allow for the moisture content of the fine aggregate. This test shall be repeated whenever there is reason to believe that the moisture content of the fine aggregate has changed since the previous test was made.

(c) Reinforcing steel shall be sampled at the mill, and test reports to establish compliance with the specifications for each type of reinforcing steel shall be submitted.

(d) Fresh concrete to be placed in stationary formwork shall be sampled as described in ASTM C172-90, "Sampling for Fresh Concrete", or equal.

(e) Slump tests shall be made frequently to control the fresh concrete before its final placement and these tests shall be made in accordance with the ASTM C143-90 for "Test for Slump of Portland Cement Concrete", or equal.

(f) Molded Concrete Test Specimens: One set of four specimens shall be made and tested from each 100 cubic yards (80 cubic meters) of concrete or fraction thereof, or each day's poured, whichever is less. Specimens shall be molded and cured in accordance with the procedure in ASTM C31-90 for "Making and Curing Concrete Compression and Flexural Test Specimens in the Field", or equal, and the mold shall conform to the ASTM C470-87 for "Molds for Forming Concrete Test Cylinders Vertically", or equal.

(g) Concrete Specimen Testing: The standard age of tests shall be 28 days; however, seven day and even three-day tests may be required by the Engineer.

Test specimens for determining when a structure may be placed in service and test specimens for acceptance of concrete shall be tested in accordance with the procedure in ASTM C39-86 for "Compressive Strength of Cylindrical Concrete Specimens", or equal.

The test result shall be the average of the strengths of two 28-day tests, except that if one specimen in a set of four shows evidence of improper sampling, molding, or testing, the test result of that specimen shall be discarded and the resulting test of another specimen of the same set shall be inserted in its place. If two specimens in a set of four show such defects, the result of the tests shall be discarded and the average strength shall be determined from test results of the remaining two specimens. If the average of the strength tests of the specimens for any portion of the work falls below the minimum allowable compressive strength at 28 days required for the class of concrete used in that portion, the Engineer shall order a change in the proportions of the cement and aggregates or the water content of the concrete, or both, for the remaining portions of the work.

If cube specimens are made and tested instead of cylinders, the cube strength shall be 25 percent higher than the cylinder strengths specified in Section 8, "Kind of Concrete, Strength Requirements, and Usage".

(h) Hardened concrete shall be tested when the results of tests of the control specimens indicate the concrete as placed does not meet specification requirements or when there is other evidence that the quality of concrete is below specification requirements.

One or all of the following tests may be required by the Engineer's Representative.

- Concrete test hammers may be used for testing when approved by the Engineer. However, if test results fall consistently below the required compressive strengths for the concrete, cored shall be drilled from the hardened concrete in the questionable area and shall be tested to determine whether the concrete remains in place or is to be removed. The hammer shall be calibrated and testing shall be conducted on surfaces that are smooth and uniform with no rough spots, honeycomb or porous area. The tests shall not be made on sections less than 4 inches (10 cm) in thickness unless it is backed up by a heavy mass placed against the backside. If the surface is rough a grinder shall be used to prepare a smooth surface for testing.
- Cores, when required by the Engineer, shall be drilled and tested in accordance with ASTM C42-84a for "Obtaining and Testing Drilled Cores and Sawed Beams of Concrete", or equal.
- Load Tests : Where core drilled test results indicate that the in-place concrete does not meet specification requirements, a load test shall be conducted in accordance with the applicable section of the American Concrete Institute Building Code (ACI 318), or equal.

(i) Water: Where the presence of deleterious materials is suspected, a mortar test shall be made. The strength at 28 days of mortar specimens made with the water under examination and ordinary portland cement shall be at least 90 percent of the strength of similar specimens made with the same cement and with water of known satisfactory quality. Steps shall be taken in the field to ascertain whether the water in the vicinity meets specification requirements applying to its use in mixing and curing of concrete and in aggregate washing operation : and also whether the soil or water with which the concrete will be in contact contains harmful sulfate concentration.

(j) Admixture: Certificates shall be submitted that the concrete containing admixtures maintains strength increases over a period of at least two years, that drying shrinkage is reduced, that uniformity in mix is maintained, and that an admixture of the exact composition proposed has been successfully employed in work of similar scope for at least five years.

(k) Materials not Mentioned: The testing of all materials not specifically mentioned shall be done by generally accepted methods and standards of ASTM or equal.

2.3.6 Examples of Test Methods for Aggregate

(a) Related Standards (ASTM)

Characteristics	Test Standards
Definition of constituents	ASTM C 125, ASTM C 294
Aggregate constituents	ASTM C 40, ASTM C 87, ASTM C 117, ASTM C 123, ASTM C 142, ASTM C 295
Particle shape and surface texture	ASTM C 295, ASTM D 2298
Relative density	ASTM C 127 (fine), ASTM C 128, ASTM C 566
Grading	ASTM C 117, ASTM C 136
Void content	ASTM C 1252
Bulk density	ASTM C 29
Phisical properties	ASTM C 33
Chemical properties	ASTM C 33
Abrasion resistance	ASTM C 131, ASTM C 535, ASTM C 779
Sulfate resistance	ASTM C 88
Concrete strength	ASTM C 39, ASTM C 78
Fine aggergate degradation	ASTM C 1137
Alkali resistance	ASTM C 227, ASTM C 289, ASTM C 295, ASTM C 342, ASTM C 586, ASTM C 1260, ASTM C 1293

(b) Aggregate sampling

◦ Preliminary inspection and adequacy of the material production area, inspection of materials at the time of shipment, and inspection of materials during construction

(a) Sampling method

(1) Stone in the quarry

- Carefully examine the color and texture of the quarry surface and record the change in each layer.
- Samples of 25 kg or more should be collected for each rock layer with different color

and texture. At this time, samples should not be taken from the weathered part. When it is necessary to test the toughness and compressive strength of a rock, it should be collected in a size of 150 mm or more in width and 100 mm or more in thickness, and the grain of the rock should be marked. In addition, there should be no damage to the sample by cutting or crushing or blasting.

(2) Stone or boulder in the open air

- The types and distribution of materials are to be investigated in detail throughout the entire area of the mountain area.

- For each stone that can be used as a structural material, samples of 25 kg or more are to be collected.

(3) Sand or gravel produced around the construction site

- Representative samples are to be taken for various materials in the production area and the quantity of the materials must be estimated.

- In case of open-pit mining, a representative sample of the material to be used is collected by excavating a vertical sphere from the top to the bottom, and topsoil and other materials should not be mixed into the sample. In addition, several test holes should be dug to investigate the nature and distribution of the material.

- Collection by quadrant method

- In the case of sand, remove the dry sand on the surface and collect a representative sample from the wet sand on the inside

(4) Sampling at the production plant

Factory facilities should be inspected, and representative samples should be collected at appropriate locations when loading from piles or storage into vehicles. In order to check the change in particle size, a separate sample is collected from time to time during loading. When collecting a sample from the storage, it is taken over the entire cross section of the material flowing out of the outlet, and when the discharge starts, it should be collected after a uniform flow.

(c) Aggregate sieve test

◦ A test to determine whether the aggregate is appropriate as an aggregate, such as particle size, assembly rate, and maximum size.

◦ If the particle size of aggregate is appropriate, the unit mass of aggregate is large, cement paste is saved, and concrete with high density is obtained, which is economical.

(a) Test apparatus:

(1) Scales: those with an accuracy of 0.1% or less of the sample weight

(2) Standard body/fine body [0.075mm, 0.15mm, 0.3mm, 0.6mm, 1.2mm, 2.5mm, 5mm, 10mm] Thick body [5mm, 10mm, 15mm, 20mm, 25mm, 30mm, 40mm, 50mm, 65mm, 75mm, 100mm]

(3) Dryer: One that can maintain a constant temperature of 105±5℃

(4) Sample collector, shovel, sample pan, etc.

(b) Test method:

(1) Sample preparation

- Sampling: A representative sample is collected using a quadrant method or a sample collector.

- If coarse and fine aggregates are mixed, apply coarse aggregate to what remains in the 5.0 mm sieve, and fine aggregate to pass through, and collect the required amount according to the particle size of each.

(2) Sample drying

- After drying at 105±5℃ until it becomes a constant mass for 24 hours, the sample is cooled to room temperature.

(3) Sieving

- Work until passing through each sieve for 1 minute is less than 0.1% of the total mass of the sample.

(4) Residual amount measurement by sieveby sieve

- After sieving is finished, measure up to 0.1% or more of the sample mass. The total sample mass after the test should not differ by more than 1% from the sample mass before the test.

(5) Calculate the result

- Calculation of pass volume and pass percentage by sieve (1 decimal place)

- Calculate the maximum aggregate size and the amount of 0.08mm sieve passing, and find the fineness modulus (F.M).

- On the abscissa axis, the size of the sieve is a logarithmic scale, and on the ordinate axis, the mass (%) of the sample remaining in each sieve is plotted as a dot.

(6) Calculate fineness modulus (F.M)

- The fineness modulus of coarse aggregate is the sum of the accumulated residual rate of the remaining amount of each sieve below.

$$F.M. = \frac{(75mm + 40mm + 20mm + 10mm + 5mm + 2.5mm + 1.2mm + 0.6mm + 0.3mm + 0.15mm)}{100}$$

- The fineness modulus of fine aggregate is the sum of the accumulated residual rate of the remaining amount of each sieve below.

$$F.M. = \frac{(5mm + 2.5mm + 1.2mm + 0.6mm + 0.3mm + 0.15mm)}{100}$$

(7) Application of fineness modulus (F.M)

- In general, the fineness modulus of fine aggregate is 2.3 to 3.1, and the fineness modulus of coarse aggregate is 6 to 8. The fineness modulus of fine aggregate for concrete applies 2.3 to 3.1, and if it is out of this range, the formulation should be modified.

(d) Density and absorption rate test of coarse aggregate

◦ To measure the durability and strength of aggregates and to know the absolute volume of aggregates, the higher the density, the greater the strength, the less the absorption, and the greater the durability against freezing.

◦ Coarse aggregate absorption test is performed to know the voids in coarse aggregate grains or to control the amount of water used in the calculation of concrete mix.

(a) Test apparatus:

Scale (thing that can read within 0.1% of sample mass), wire mesh, dryer, water tank, absorbent cloth, sieves

(b) Test method:

(1) Sample preparation

i) As for the sample, take a representative sample, and the coarse aggregate remaining on a sieve with a nominal size of 5 mm is reduced by a quadrant method or a sampling sieve until it becomes almost a certain amount.

ii) The minimum mass of the sample used for one test of ordinary aggregate shall be 0.1 times the maximum dimension (in mm) of coarse aggregate, expressed in kg. For lightweight aggregate, approximate sample mass is determined according to the following formula.

$$m_{min} = \frac{d_{max}\ xD_e}{25}$$

m_{min} : Minimum mass of the sample (kg)

d_{max} : Maximum dimension of coarse aggregate (mm)

De : Estimated density of coarse aggregate (g/㎤)

iii) Wash the sample sufficiently with water and remove impurities and other foreign substances from the particle surface.

(2) Test Procedure

i) Put the sample in a wire mesh, vibrate in water, remove air attached to the particle surface and particles, and then immerse in water at 20±5°C for 24 hours.

ii) Measure the mass (C) and water temperature in water at 20±5℃.

iii) Take the sample out of the water, remove the water, roll the sample on an absorbent cloth, remove the visible water film, and measure and record the mass (B) in the dry saturated state.

iv) Dry the sample at 105±5°C to a constant mass, cool to room temperature, and measure the absolute dry mass (A).

v) Density is calculated according to the following formula.

- Density in absolute dry state (D_d) = $\frac{A}{B-C}\ x\ \rho_w$

- Density in dry saturated state (D_s) = $\frac{B}{B-C}\ x\ \rho_w$

- True density (D_A) = $\frac{A}{A-C}\ x\ \rho_w$

A : Mass of sample in absolute dry state (g)

B : Mass of sample in saturated state of surface dryness (g)

C : Mass of sample in water (g)

ρ_w : Density of water at test temperature (g/cm^3)

vi) The absorption rate indicating the amount of absorption is calculated according to the following formula.

Absorption rate = $\frac{B-A}{A}\ x\ 100(\%)$

vii) The average value of the two tests shall be the density and water absorption of coarse aggregate, and the difference from the average value shall be 0.01 g/cm3 or less of the value in the case of density and 0.03% or less in the case of a water absorption test.

(c) Application:

i) The density of coarse aggregate is about 2.50 to 2.70, and the absorption should be 2.5% or less.

ii) Density of aggregate for dam concrete is 2.60 or higher as a standard

(e) Density and absorption rate test of fine aggregate

◦ This test is performed to determine the general properties of fine aggregates and to know the absolute volume of fine aggregates when designing a concrete mix.

◦ Estimate the unit mass of concrete and the strength or absorption rate of the aggregate itself through the density of the fine aggregate.

◦ Absorption rate indicates the degree of voids inside the aggregate, and is a criterion for judging whether the aggregate is good or bad.

(a) Test apparatus:

Scales, flasks, conical molds, compaction rods, dryers, etc.

(b) Test method:

(1) Sample preparation

i) For samples, take representative samples, prepare about 1000 g of fine aggregate by a sample separator or quadrant method, put it in an appropriate pan or bowl, and dry it at a temperature of 105±5℃ until it reaches a certain amount, then 24±4 time soak in water. Keep the water temperature at 20±5℃ for at least 20 hours.

ii) Spread the sample on a flat container and dry it slowly in warm air. Shake the sample frequently to ensure uniform drying, and this operation should be continued until the water in the fine aggregate is almost gone.

iii) Slowly put fine aggregate into the conical mold without compaction, then flatten the top surface, and then compact it 25 times with a compactor without applying force. After compaction, the remaining space should not be refilled, but lifted vertically.

iv) If there is surface water, the cone of fine aggregate will not flow down and will maintain its state. When the mold is lifted, the fine aggregate should be continuously blown dry until the cone of fine aggregate flows down, and this test should be repeated frequently.

v) The first flowing down of the cone of fine aggregate means that the fine aggregate has reached the surface dry saturation state.

vi) If the cone flows down when the mold is removed in the first test, it means that the fine aggregate has dried beyond the limit of surface dry saturation.

(2) Test Procedure

i) Collect 500 g or more prepared according to the above method and measure the mass to 0.1 g. Put the sample in a flask immediately, fill it with water up to 90% of its capacity, and roll the flask on a flat surface to stir to remove all air bubbles. Then, measure the temperature. Then, immerse the flask in a constant temperature water bath for about 1 hour, adjust the temperature to 20±5°C, measure the mass of the flask, sample, and water, and record this mass and other masses to 0.1 g.

ii) After removing the fine aggregate from the flask, dry it at 105±5°C for about 24 hours, cool it in a desiccator to room temperature, and weigh up to 0.1g.

iii) When measuring the water temperature, the temperature difference in i) should not exceed 1°C.

(3) Calculation

i) Density in absolute dry state (d_d) = $\frac{A}{B+m-C}\ x\rho_w$

ii) Density of surface dry saturated state (d_s) = $\frac{m}{B+m-C}\ x\rho_w$

iii) True Density (d_A) = $\frac{A}{B+A-C}\ x\rho_w$

iv) Absorption rate = $\frac{m-A}{A}\ x\ 100(\%)$

A: Mass (g) of sample in absolute dry state

B: Mass (g) of flask filled with water up to the scale indicating the calibrated capacity

C: The mass of the flask filled up to the scale indicating the calibrated volume with sample and water (g)

ρ_w : Density of water at the test temperature (g/㎤)

m: mass of surface dry saturated sample (g)

v) For precision, the above test is performed twice, and the difference between the average value should be 0.01 g/cm^3 or less of the value in the case of density test, and 0.05% or less in case of water absorption test.

(f) Abrasion test of coarse aggregate

◦ This is a test to measure the hardness of aggregates.

◦ When abrasion resistance is required, such as road concrete and dam concrete, it must be rigid.

(a) Test apparatus:

Los Angeles testing machine, scale, sieve, etc.

(b) Test method:

(1) Sample preparation

i) Sieve coarse aggregates into meshes of 2.5 mm, 5 mm, 10 mm, 15 mm, 20 mm, 25 mm, 40 mm, 50 mm, 65 mm and 75 mm.

ii) From among the particle size classifications shown in the table below, select the one (among A to H) closest to the particle size of the aggregate to be tested.

iii) After washing the aggregate to be tested, dry it at a temperature of 105±5°C until it becomes a certain mass, and take it according to the selected particle size and use it as a sample. The mass of the sample shall be the value shown in the table below after drying.

<Mass of Abrasion Test Specimens by Los Angeles Testing Machine>

Particle division	Range of particle diameter divided by the nominal dimension of the mesh (mm)	Mass of sample (g)	Total mass of sample (g)
A	10-15	1250±10	5000±10
	15-20	1250±10	
	20-25	1250±10	
	25-40	1250±10	
B	15-20	2500±10	5000±10
	20-25	2500±10	
C	5-10	2500±10	5000±10
	10-15	2500±10	
D	2.5-5	5000±10	5000±10
E	40-50	5000±10	10000±10
	50-65	2500±10	

	65-80	2500±10	
F	25-40	5000±10	10000±10
	40-50	5000±10	
G	20-25	5000±10	10000±10
	25-40	5000±10	
H	20-10	5000±10	5000±10

(2) Test Procedure

i) According to the particle size classification of the sample, select the number of spheres shown in the table below, put this together with the sample in a cylinder

ii) Close the cover and rotate at 30 to 33 revolutions per minute, 500 revolutions in case of particle size classification of A to D and H, and 1,000 revolutions in case of particle size E to G.

iii) Take the sample out of the testing machine and sieve it with a mesh sieve of 1.7 mm.

iv) Wash the sample remaining on the sieve with water, dry it at a temperature of 105±5℃ until it reaches a certain mass, and weigh it.

(3) Calculation

The abraison loss is calculated according to the following formula and ends at the first decimal place.

$$R = \frac{m_1 - m_2}{m_1} \ x \ 100(\%)$$

Where R : Abraison loss (%)

m1 : Mass of sample before test (g)

m2 : Mass of sample remaining in 1.7mm of mesh after test (g)

(c) Application:

i) The limit of the abraison loss (percentage) of coarse aggregates should be 50% or less.

- Grain size adjuster layer, asphalt base layer, cement stabilizer base layer: 40% or less
- Concrete pavement: 35% or less, general concrete aggregate 40% or less

ii) The steel ball used for the test must be made of cast iron or steel with a diameter of 46.8 mm and a mass of 390 to 445 g.

iii) In general, the smaller the abrasion loss of coarse aggregate, the less the loss of concrete wear.

iv) When the rock is tested in a particle shape that is close to cubic, the abrasion loss is about 85% of that of crushed stone made from the same rock.

(g) Testing method for organic impurities contained in sand for concrete

◦ This test is conducted to outline organic impurities contained in natural sand used for mortar and concrete.

◦ Organic impurities that contaminate aggregates are included in peat and humus, and even when the amount does not reach 1%, they interfere with the hardening of concrete and impair the strength, durability, and stability of concrete.

◦ Organic impurities contained in sand are usually in the form of corroded plant matter, and the washed sand contains few organic impurities.

(a) Test apparatus:

2 test glass bottles, sodium hydroxide solution, tannic acid solution, sampler, measuring cylinder, balance, identification standard solution, pipette, etc.

(b) Test method:

(1) Preparation of standard color solutions

i) Make a 2% tannic acid solution with 10% alcohol solution.

ii) Mix 97% water with 3% sodium hydroxide (caustic soda) in a mass ratio to make a 3% sodium hydroxide ($NaOH$) solution.

iii) Take 2.5 ml of tannic acid and 97.5 ml of 3% sodium hydroxide solution.

iv) Put this in a colorless glass bottle with a capacity of about 400ml, close the stopper, shake it well, and leave it for 24 hours. This is used as a standard color solution.

(2) Sample: Approximately 450 g of a representative sample is taken by the quaternary method or a sample separator.

(3) Put the sample in a colorless transparent glass bottle for testing up to a scale of 130 ml.

(4) Add 3% sodium hydroxide solution to the scale of 200 ml.

(5) Cap the bottle, shake well, and let stand for 24 hours.

(c) Judgment of results

i) Compare the color of the transparent solution on the top of the sample with the color of the standard solution and record whether it is light, dark, or the same.

ii) If the chromaticity of the test solution is lighter than that of the standard solution, the sand is acceptable.

iii) Fine aggregate with a color darker than the standard color should not be used.

2.3.7 Storage

(a) Cement shall be stored in a dry, weather tight, properly vented structure with a wooden floor raised not less than 12 inches (30.48 cm) above the ground and having adequate provision for prevention of absorption of moisture. Different brands of cement shall be stored separately and shall not be mixed. Notwithstanding and previous acceptance, any bag of cement containing material which has hardened or otherwise deteriorated shall be rejected, and any cement rejected for any cause shall be removed from the site immediately. Cement which has been stored on the site for more than six months, shall not be used in the works and shall be removed from the site.

(b) Aggregate shall be stockpiled in locations providing good drainage and where inclusion of foreign matter will be prevented and the gradation may be preserved. Sufficient live storage shall be maintained to permit separation of shipments from different sources, and to assure placement of concrete at the required rate. Frozen or partially frozen aggregates shall not be used.

- Fine aggregate from different sources of supply shall not be mixed or stored in the same stockpile, nor used alternately in the same class of construction without the approval of the Engineer.
- Coarse aggregate shall be stockpiled in such a manner that it is not contaminated by fine aggregate. Adequate precautions shall be taken to prevent segregation while it is being transported and stockpiled.

(c) Reinforcing steel shall be stored in a manner that will prevent it from being damaged and to preserve the identification of the various pieces. The temperature of the reinforcing shall be kept below 90 degrees Fahrenheit (32 Celsius).

(d) Other concrete materials shall be stored to provide protection from the weather.

2.3.8 Delivery of Materials

Trucks used for transporting portland cement, water, aggregates, and reinforcing steel shall be clean when any of these materials are placed therein. Trucks and other vehicles used to transport materials must be kept clean and free from foreign matter.

They must be in proper working condition and have strong, substantial bodies, which will prevent the loss of materials during transportation.

2.3.9 Kind of Concrete, Strength Requirements, and Usage

(a) All Structural concrete for water retaining structures, unless otherwise specified herein, shall have a minimum compressive strength of 30MPa at 28 days.

(b) All structural concrete for buildings shall have a minimum compressive strength of 24MPa at 28 days.

(c) Lean concrete shall be concrete used for fill material when required by the Engineer's Representative for hopper fills in bin bottoms and for leveling beds. Lean concrete shall attain a minimum compressive strength of 14MPa at 28 days.

(d) Grout: Cement grout and non-shrink grout shall be used at locations shown or specified and shall attain a minimum compressive strength of 30MPa at 28 days.

(e) Control: The strength quality of the concrete proposed for use shall be established by tests made in advance of the beginning of operations, using the consistencies suitable for the work. Trial mix design and testing shall be the responsibility of the Contractor. The contractor shall make trial mixes in the presence of the Engineer.

Test specimens shall be made of each trial mix and shall be tested at 28 days. If the trial mix shall fail to attain the strength and workability required, the Engineer may order further trial mixes to be made until an acceptable mix is obtained.

2.3.10 Proportioning of Concrete Mixes

(a) Measurement of concrete materials shall be by weight on weighing equipment and scales approved by the engineer's representative. Measuring devices shall be as nearly automatic as practicable and shall be so calibrated that the contents of any setting may be readily determined. When measuring devices are not available, the proportions shall be such that the water-cement ratio does not exceed the appropriate value shown in following table.

Maximum Permissible Water-Cement Ratios (Method 3 of ACI 304-73)

Specified Strength, fc, psi (kPa)	**Max. Permissible Water-Cement Ratio by Weight***	
	Non-Air-Entrained Concrete	**Air-Entrained Concrete**
4,000 (27,580)	0.44	0.35
3,750 (25,856)	0.48	0.38
3,500 (24,132)	0.51	0.40
3,000 (20,685)	0.58	0.46
2,500 (17,237)	0.65	0.54

* Including free surface moisture on aggregates, and liquid admixtures.

Fine and coarse aggregates shall be measured separately.

(b) All Structural concrete shall be mixed in such proportions as will result in a workable mix having a minimum cement content of 600.0 pounds per cubic yard (356 kg/m^3) of concrete. The mix shall be designed for a required compressive strength of 3,000 pounds per square inch (20,685 kPa) in 28 days.

(c) Lean concrete shall be mixed in such proportions as will result in a workable mix having a minimum cement content of 200 pounds per cubic yard (119 kg/m^3) of concrete. Aggregate shall be clean, well graded sand and gravel or crushed stone.

(d) Concrete topping shall be mixed in such proportions as will result in a workable mix having a minimum of 100 pounds (45.36 kg) of portland cement to 300 pounds (136 kg) of sand. Aggregate shall be clean, well graded sand.

(e) Grout

- Cement grout shall consist of 100 pounds (45.36 kg) of portland cement to 200 pounds (90.72 kg) of clean, well graded sand. The sand shall contain approximately 25 percent material passing the No. 50 screen. The mortar shall be no wetter than necessary for satisfactory placement.
- Non-shrink grout shall consist of 100 pounds (45.36 kg) of portland cement to 200 pounds (90.72 kg) of clean, well graded sand and shall be mixed with an oxidized, uniformly graded, processed metallic powder blend with a select oxidizing agent.

- A non-shrink grout of fluid consistency shall be used only when authorized by the Engineer's Representative.
- Slump: The proportions shall be such as to produce a mixture which will work readily into the corners and angles of the forms and around reinforcing with the method of placing employed on the work, but without permitting the materials to segregate or excess free water to collect on the surface. The amount of water shall be the minimum necessary to produce concrete of the workability required by the engineer's representative. Slumps shall range as follows:

Description	Maximum	Minimum
Structural concrete (general)	4 inches (10.16 cm)	2 inches (5.08cm)
Lean concrete	4 inches (10.16 cm)	2 inches (5.08 cm)

(f) Durability: Concrete of normal weight which will be subject to potentially destructive exposure (other than wear or loading) such as freezing and thawing, severe weathering of deicer chemicals shall be air entrained and shall conform to the air content limits of the following table as measured by "Test for Air Content of Freshly Mixed Concrete by the pressure method" (ASTM C231), "Test for Air Content of Freshly Mixed Concrete by the Volumetric Method" (ASTM C173), or "Test for Weight Per Cubic Foot, Yield and Air Content (Gravimetric) of Concrete" (ASTM C138) : the water-cement ratio shall not exceed 0.53 by weight.

Total Air Content for Various Sizes of Coarse Aggregate for Normal Weight Concrete (ACI 304-73)

Nominal Max. Size of Coarse Aggregate, In (cm)*	Size Number	Total Air Content, Percent by Volume
3/8 (0.95)	8	6-10
½ (1.27)	7	5-9
¾ (1.90)	67	4-8
1 (2.54)	57	3.5-6.5
1~1 ½ (2.54~3.81)	467	3-6
2 (5.08)	357	2.5-5.5
3 (7.62)	-	1.5-4.5

2.3.11 Ready Mixed Concrete

Where ready-mix concrete is proposed for use, the mixing and transporting equipment and the method of placement shall be subject to approval of the Engineer. Except for materials specified herein, ready-mix concrete shall conform to ASTM Standard C94-90 for "Ready-Mixed Concrete", or equal.

2.3.12 Batching of Materials

(a) General: Batching of materials may be done in either a manual or a semi-automatic plant subject to the approval of the Engineer. A manual plant is one in which batch weights are set manually and materials are batched manually. A semi-automatic plant is one in which batching are set manually, mixes are changed manually, and materials are batched automatically.

Separate bins of compartments shall be provided for fine aggregate, for the different size of coarse aggregate and for bulk cement when used.

The Compartments shall be of ample size and so constructed that the materials will remain separated under all working conditions. Aggregates may be weighed cumulatively in one weigh batcher on one scale in a manual plant and in a semi-automatic plant may be weighed cumulatively in one-weigh batchers on one scale or in separate weigh batchers with individual scales. In a semi-automatic plant, bulk cement shall be weighed on a separate scale in a separate weigh batcher. In a manual plant, bulk cement shall be weighed in a separate hopper that may be attached to a separate scale for individual weighing, or may be attached to the aggregate hopper for cumulative weighing, provided there are separate beams or dials for cement and aggregates. If cement is weighed on the same scale as the aggregates, the cement shall be weighed first and interlock shall be provided to insure that all hoppers are empty and that the scale is in balance before the weighing of the cement is begun. In a semi-automatic plant, the batching controls shall be so interlocked that a new batching cycle cannot be started until all catches are completely empty. The plant shall be arranged as to facilitate the inspection of all operations at all times. Suitable facilities shall be provided for obtaining representative samples of concrete for uniformity tests. Delivery of materials from the batching equipment shall be within one percent for cement, water and admixture, and two percent for aggregates.

(b) Equipment for batching water and admixture shall be provided at the batching plant, or included with the mixer, as required for the type of plant used. A suitable water measuring device shall be provided that will be capable of measuring the mixing water within the specified requirements for each batch. The mechanism for delivering water to the mixers shall be such that leakage will not occur when the valves are closed. The filling and discharge valves for the water batcher shall be so interlocked that the discharge valve cannot be opened before the filling valve is fully closed. Where admixtures are added to the water, a suitable device for measuring and dispensing the admixtures shall be provided which shall meet the approval of the Engineer.

(c) Scales: Adequate facilities shall be provided for the accurate measurement and control of each of the materials entering each batch of concrete. The contractor shall provide standard test weights and any other auxiliary equipment required for the operation of each scale or other measuring device. Periodic tests shall be made in the presence of the Engineer and at his direction. Upon completion of each check test and before further use of indicating, recording or control devices, the Contractor shall make such adjustments, repaired to secure satisfactory performance. The weighing equipment shall be arranged so that the plant operator can conveniently observe all dials or indicators.

2.3.13 Concrete Mixes

Concrete mixers may be either the stationary or transit type. All mixers shall be maintained in a satisfactory operating condition, and mixer drums shall be kept free of hardened concrete. Mixer blades shall be replaced when worn down more than 10 percent of their depth. The use of any mixer that at any time produces unsatisfactory results shall be promptly discontinued until the mixer is repaired. The mixer shall be equipped with adequate water storage, a device for accurately measuring the amount of water stored and a device for accurately measuring the amount of water in each batch. It shall be equipped with a batch meter or other device for accurately recording the number of revolutions for each batch, and an attachment for automatically locking the discharging device so as to prevent the emptying of the mixer until the materials have been mixed the specified minimum time. Upon cessation of mixing for more than 30 minutes, the mixer shall be thoroughly cleaned. Transit mixers shall be operated within the limits of capacity and speed of rotation designated by their manufacturers. Delivery of concrete to the site of work and its discharge from the truck mixer shall be completed within 1/2 hour after the introduction of the mixing water to the cement and aggregates, or the cement to the aggregates, unless otherwise authorized by the Engineer.

2.3.14 Mixing Concrete

Mixing concrete shall be done in a batch mixer of an approved type and size, and one so designed as to positively insure a uniform distribution of materials throughout the mass. All concrete shall be thoroughly mixed, after all materials and water are in the mixer, for a period of not less than 1-1/2 minutes for mixers with a capacity of one cubic yard or less, and not less than two minutes for larger mixers. The mixing time shall be increased when such increase is necessary to secure the required uniformity and consistency of the concrete and shall be at the direction of the Engineer. Excessive over-mixing requiring additions of water will not be permitted. Remixing, re-tempering, or placing concrete or mortar which has partially hardened or has begun its initial set will not be permitted under any circumstances.

2.3.15 Forms

Forms in general shall be suitable and substantial for all structural concrete, and where required, for plain concrete. All required forms, adjustable shores, bracing, column clamps, form ties and other accessories shall be provided.

All formwork will be subject to the Engineer's approval, but responsibility for its safety and adequacy shall remain with the Contractor. All types of forms may be reused if approved as suitable by the Engineer. Forms shall be nailed, bolted, or tied securely together with all required bracing and shoring. Opening with closure panels shall be provided at the bottoms of forms for walls, beams, girders, grade beams, piers, and columns and shall be properly spaced to facilitate inspection and cleaning out of forms. All forms shall be of sufficient strength to support construction loads and the weight of plastic concrete together with moving loads of men and materials. Design, erection, maintenance and removal of all concrete formwork including bracing and shoring shall conform to the requirements of the "Recommended Practice for concrete Formwork" (ACI-347), or equal, unless specified otherwise herein.

Stationary forms for all exposed finished surfaces shall be built of metal, plywood, pressed wood, or dressed tongue and grooved lumber and shall be built, so that when removed, the concrete will be left with a smooth surface, free from offsets, fins, ridges, or other unsightly defects. Forms shall conform accurately to the shape, lines, and dimensions shown on the drawings. All interior and exterior exposed concrete shall be formed with material that will produce surface finishes equal to surfaces produced by new, tight, clean, plastic surfaced plywood. Forms for unexposed concrete may be of sound plank material or sound salvaged plywood. All forms shall be tight to prevent leakage of mortar and shall be constructed and held plumb and true to line. Forms for securely braced, tied, clamped and shored, and shall be fireproofing structural steel shall be so constructed as to insure proper and complete filling and placement, especially in locations of minimum coverage. One half-inch visual check holes shall be provided. A coat of non-staining oil or lacquer shall be applied to protect the form surface material and to facilitate stripping. Form coatings shall be applied to the forms in accordance with the directions of the manufacturer. Where concrete surfaces are to be painted and where other material is to be applied with adhesive directly to concrete (such as soffits and ceilings that are to be plastered), contact surfaces of forms shall be coated with lacquer type sealing coating.

All screeds shall be so constructed as to produce continuous plane surfaces. Screeds shall be set sufficiently ahead of placement of concrete so as to cause no interruption of placing operations, and shall be sturdy and so designed as to leave no undesirable marks prior to placing concrete permanently in the forms. All forms shall be cleaned of wood, shavings, trash, mud, water, and foreign substances, and shall be dampened. All forms shall be thoroughly cleaned before reusing. Studs shall be placed close enough together to prevent deflection of form material and consequent variation in the surface of the concrete.

Slots, chases, recesses and openings in concrete for other work shall be provided. All wall ties, fixtures, frames, sleeves, weld plates, anchors, dowels, nailing blocks, and similar items shall be built into the form construction. Built-in items shall be in their correct locations and securely anchored to the forms.

Concrete shall be blocked out or sleeves shall be installed when pipe or conduit runs through the webs of beams or girders. The type of installation and the location shall be approved by the Engineer's Representative.

Beam and girder forms shall be built so that the sides may be removed without disturbing the bottoms and the centering shall be crowned at least 1/4 inch (6.4 mm) for each 10 feet (3 m). Forms shall not be erected on concrete footings until the concrete in the footings has cured 36 hours. Shoring under beam, girder and slab construction shall be done with approved shores, which are properly braced to support required loads. All column forms shall be properly braced. Forms shall be inspected and approved prior to each concreting operation.

(a) Form Design: The anticipated deflection in the forms due to weight of fresh concrete shall be accurately figured and taken into account in the design of the forms, so that finished concrete members will have true surfaces conforming accurately to desired lines, planes, and elevations shown on the drawings. Forms shall be constructed so that they can be removed without injury to the concrete. Joints shall be sufficiently tight to prevent leakage of grout during placing and shall be arranged vertically or horizontally to conform to the pattern of the design. Forms placed on successive units for continuous surfaces shall be fitted to accurate alignment to assure a smooth completed surface free from irregularities. If adequate foundation for shores cannot be secured, trussed supports shall be provided.

(b) Form ties shall be either pull-through type or snap ties that will break back at least 3/4 inch (19 mm)from surfaces. Wire ties passing through the concrete and wood spreaders may be used after approval of Engineer. Bolts and tie-rods that are to be completely withdrawn shall be coated with grease. Tie rod clamps to be entirely removed from the wall shall be loosened 24 hours after concrete is placed, and form ties, except for a sufficient number to hold forms in place, may be removed at that time. Ties wholly withdrawn from walls shall be pulled toward the inside face.

(c) Filling Tie-Rod and Bolt Holes: Holes left by bolts or tie-rods shall be filled solid within 12 hours after removal of forms, with cement mortar blended to match the adjacent surface. Holes passing entirely through wall shall be filled from the inside face with a device that will force the mortar through to the outside face, using a stop held at the outside wall surface to insure complete filling. Excess mortar at face of filled holes shall be struck off flush.

(d) External corners of columns, girders, beams, foundations, walls projecting beyond overlying masonry, and other external corners not protected by structural steel shall be chamfered by 3/4 inch (19 mm) moldings placed in the forms, unless otherwise shown on the drawings.

(e) Removal of forms shall be in such a manner as to insure the complete safety of the structure. The removal of forms and shores shall require the approval of the Engineer, but the Engineer's acquiescence to removal shall not relieve the Contractor from responsibility for the removal or from the adequacy and safety of formwork and structure. In no case shall supporting forms or shoring be removed until the concrete members have acquired the strength required to safely support their own weight and the load thereon. In no case shall forms used for curing be removed before expiration of curing period, except as provided under the paragraph entitled "Curing".

Normally, formwork may be removed after the following periods have elapsed

- Beam Sides, Walls and Columns (unloaded) - ------------3 days
- Slabs (props left under) ------------------------------------ 10 days
- Removal of Slab Props (unloaded) ----------------------- 14 days
- Beam Soffits (props left under) --------------------------- 14 days
- Removal of Beam Props (unloaded) ---------------------- 21 days

Care shall be taken to avoid spalling the concrete surface. Wood forms shall be completely removed from under steps and similar spaces. Immediately upon removal of the forms, the surface shall be carefully examined, and any irregularities of the surface shall be treated as directed by the Engineer. Honeycombed portions of concrete shall be cut out to the extent of such defects and the space refilled with concrete or mortar at the direction of the Engineer. Merely plastering over such defects will not be permitted.

If for any reason the formwork moves after the concrete has been placed, thus disturbing the freshly-placed concrete, or if the concrete is found to be out of alignment, the Contractor may be ordered to remove and replace such concrete without extra payment.

(f) Tolerances : Unless other wise specified by the Engineer, formwork shall be constructed so that the concrete surfaces will conform to the tolerance limits listed below.

Tolerances for Formed Surfaces

(1) Variation from plumb

- In the lines and surfaces of columns, piers, walls, and in arrises
  - In any 10 ft (3 m) of length — 1/4 in (6.4 mm)
  - Maximum for the entire length — 1 in (25.4 mm)
- For exposed corner columns, control-joint grooves, and other conspicuous lines
  - In any 20 ft (6 m) length — 1/4 in (6.4 mm)

- Maximum for the entire length 1/2 in (12.7 mm)

(2) Variation from the level or from the grades specified in the contract documents

• In slab soffits, ceiling, beam soffits and in arrises, measured before removal of supporting shores

- In any 10 ft (3 m) of length 1/4 in (6.4 mm)
- In any bay or in any 20 ft (6 m) length 3/8 in (9.5 mm)
- Maximum for the entire length 3/4 in (19 mm)

• In exposed lintels, sills, parapets, horizontal grooves, and other conspicuous lines

- In any bay or in 20 ft (6 m) length 1/4 in (6.4 mm)
- Maximum for the entire length

(3) Variation of linear building lines from established position in plan and related position of columns, walls, and partitions

• In any bat 1/2 in (12.7 mm)

• In any 20 ftof length 1/2 in (12.7 mm)

• Maximum for the entire length 1 in (25.4 mm)

(4) Variations in the size and locations of sleeves, floor openings, and wall openings + 1/4 in (6.4 mm)

(5) Variations in cross-sectional dimensions of columns and beams and in the thickness of slabs and walls

• Minus 1/2 in (12.7 mm)

• Plus 2 in (50 mm)

(6) Footings

• Variations in dimension in plan

- Minus 1/2 in (12.7 mm)
- Plus 2 in (50 mm)

• Misplacement of eccentricity : w percent of footing width in the direction of misplacement but not more than 2 in (50 mm)

• Thickness

- Decrease in specified thickness 5 percent
- Increase in specified thickness no limit

(7) Variation in steps

• In a flight of stairs

- Rise + 1/8 in (3.2 mm)
- Tread + 1/4 in (6.4 mm)

• In consecutive steps

- Rise + 1/16 in (1.6 mm)
- Tread + 1/8 in (3.2 mm)

* Tolerances apply to concrete dimension only, not to positioning of vertical reinforcing steel, dowels, or embedded items.

2.3.16 Support Posts

(a) General

- The safety of the support post should be reviewed for vertical and horizontal loads acting during concrete construction.
- Assembled support posts and steel pipe frame support posts are installed with horizontal and inclined members to support the horizontal load.
- Support post design should consider settlement and deformation during construction and after completion.
- The distance between the vertical members of the assembled support post should be 0.9m or more and 1.2m or less. In the case of less than 0.9m, the supervisor's approval is required.
- The ratio of the spacing between vertical members to the spacing between the upper and lower horizontal members of the support post should be within the range of 0.5/1~1/1.

(b) Vertical Loads to the posts

The vertical loads used in the design of the support post are the fixed load and the working load that occurs during construction, and the values in the following paragraphs are applied.

- The fixed load is the sum of the weights of reinforced concrete and formwork. For the unit weight of concrete, 24 kN/㎥ of concrete including the weight of reinforcement bar is usually applied. The weight of the formwork should be at least 0.4 kN/m^2. However, in case of special formwork, the actual weight shall be applied.
- Working load includes construction load such as workers, light equipment load, other materials and tools required for concrete pouring, and impact load. The working load is designed to be at least 2.5 kN/m^2 per horizontal projected area of the structure when the concrete pouring height is less than 0.5 m, and 3.5 kN/m^2 when the concrete pouring height is 0.5m or more and less than 1.0m, and 5.0 kN/m^2 is applied when the height is 1.0m or more. Also, when pouring concrete using motorized carts, the design should be designed considering the working load of 3.75 kN/ m^2.
- The vertical load, which is the sum of the above fixed and working loads, is at least 5.0 kN/m^2, regardless of the concrete pouring height, The vertical load, which is the sum of the above fixed and working loads, is at least 5.0 kN/m^2, regardless of the concrete pouring height, and at least 6.25 kN/m^2 is applied when using an electric cart.

(c) Horizontal Loads to the posts

- Forms and support posts should consider the minimum horizontal load (M) due to impact or construction errors other than wind load, and review adverse cases by considering the effect of wind load and minimum horizontal load.
- The minimum horizontal load to be considered for the support post and bracing is 2% or more of the design vertical load, or 1.5 kN/m or more per horizontal length of the top of the bar, whichever is greater, shall act on the uppermost end.
- Horizontal load is applied in X direction and Y direction respectively for the support post

installation surface.

- In case the concrete pouring upper deck is inclined, the concrete fluid pressure is added to the horizontal load to be considered.
- The effect of horizontal loads that occur specially during the construction work, such as wind load (W), water pressure (F), eccentric load during asymmetrical concrete pouring, vertical and horizontal components of inclined formwork, positive pressure of concrete buried in concrete, equipment load such as cranes should be considered separately.

(d) Safety factor

The safety factor for the allowable compressive load of the support post used should be at least the following value depending on the type of support.

- Single unit support post (steel support or steel pipe that supports independently): Safety factor 3 applied
- Assembly type support post (supports the form by assembling each member such as vertical member, horizontal member, bracing, etc. on site): Safety 2.5 applied

2.3.17 Preparation for Placing Concrete

Water shall be removed from excavations before concrete is deposited. Any flow of water shall be diverted through proper side drains and shall be removed without washing over freshly deposited concrete. Hardened concrete, debris, and foreign materials shall be removed from interior of the forms and from inner surfaces of mixing and conveying equipment. Reinforcement, joint material, and embedded items shall be secured in position, inspected and approved before pouring of concrete. Runways shall be provided for wheeled concrete-handling equipment; such equipment shall not be wheeled over reinforcement nor shall runways be supported on reinforcements.

2.3.18 Placing Concrete

(a) General

Concrete shall be placed as near its final position as practicable. Concrete that has attained its initial set or has contained mixing water for more than 30 minutes shall not be placed in the work. Placing will not be permitted when the sun, heat, cold wind or limitation of facilities furnished by the Contractor prevents proper finishing and curing of the concrete. Concrete placing and finishing operations shall be done as quickly as possible. Concrete unless otherwise directed by the Engineer, shall be placed in the forms in horizontal layers not exceeding two (2) feet (0.6 m) in depth for ordinary walls, and shall be poured full depth for beams and girders and for slabs, allowing the concrete to take its natural angle of repose along the pouring line. Concrete shall be thoroughly compacted by rodding, spading, and by mechanical internal vibration, and shall be thoroughly worked around reinforcement and embedded fixtures and into corners and spaces to be filled.

(b) Placing Concrete

Concrete shall be placed in accordance with the "Recommended Practice for Measuring, Mixing and placing concrete". ACI 304, or equal. No concrete shall be placed when the atmospheric temperature is below 2°C (35°F). After concrete has been placed, if the temperature drops below 2°C (35°F), the contractor shall provide sufficient canvas and framework or other types of housing to enclose and protect the structure in such a way that the air surrounding the fresh concrete can be kept at a temperature of not less than 8°C (45°F) for a period of five days after the concrete is placed.

The Contractor shall assume all risks connected with the placing of concrete under the above conditions, and permission given by the Engineer to place concrete under the above conditions will in no way relieve the Contractor of the responsibility for satisfactory results. Should concrete placed under such conditions prove unsatisfactory it will be rejected.

(c) Mechanical internal vibrators shall be used in all formed concrete work, except where tight working space makes hand spading necessary. Systematic spacing of vibrator insertion 12 to 20 inches (30.5 to 50.8 cm) apart shall be established to insure that all concrete is thoroughly consolidated. Vibrators shall have a frequency of 5,000 vibrations per minute and shall be vertically inserted and withdrawn with 5 to 15 second vibration periods and shall be inserted to a depth that will insure penetration into the previous lift. The use of vibration as a method of moving concrete after it has been placed will not be permitted. Fresh concrete shall not be placed on concrete that has become sufficiently hard to cause formation of seams and planes of weakness within the section (cold joints).

(d) Depositing Concrete

Concrete shall not be allowed to drop freely more than three (3) feet (0.9 m) and even then shall not be allowed to hit or contact the sides of forms or reinforcing. Where greater drop heights are required, a tremie or other means approved by the tremie shall be controlled so that the concrete may be effectively compacted into horizontal layers, and the spacing of the tremie shall be such that segregation does not occur.

Pouring of concrete into place will not be permitted, except under such conditions as may be prescribed by the Engineer. If pouring is permitted, the slope of the chute shall be not less than one vertical to three horizontals or more than one vertical to two horizontals. The chute shall be so designed and operated as to prevent segregation of the aggregate and loss of mortar and the discharge end shall be provided with a baffle plate or other device to cause the concrete to drop vertically. The chute shall be thoroughly clean before and after each run. Waste material and flushing water shall be discharged outside the forms.

(e) Earth-foundation Placement

Concrete footings shall be placed upon undisturbed clean surfaces, free from mud and water. A vapor barrier of clear plastic sheeting 0.004 inch (0.1 mm) thick shall be laid over the surface to receive concrete. The contractor shall not allow water to flow over any concrete until the concrete has set at least 24 hours.

(f) Pump Placement

Where concrete is conveyed and placed by pumping, the plant and equipment shall be approved by the Engineer's Representative. Operation of the pump shall be such that a continuous stream of concrete without air pockets is produced. When pumping is completed, concrete to be used which remains in the pipeline shall be ejected without contamination of concrete or separation of ingredients. After each operation, equipment shall be thoroughly cleaned, and debris and flushing water shall be disposed of outside the forms.

(g) Underwater concreting will not be allowed.

2.3.19 Finishing Concrete

(a) Stationary form concrete

After removal of stationary forms from beams, girders, columns, and foundation walls, or any other exposed surface, the concrete shall be dressed of all irregularities and form marks to bring it to a smooth even surface. If the surface is not smooth and free from irregularities, the concrete shall be rubbed, while green, with a carborundum block until it is smooth. All cracks, voids, and from tie holes shall be puttied with mortar containing the same cement and fine aggregates that were used in the original concrete prior to the rubbing operation.

(b) Slab Finishes

Finished slab surfaces shall be true plane surfaces, with a tolerance of 1/8 inch (3.2 mm) in 10 feet (3 m) unless otherwise indicated. Surfaces shall be pitched to drains. The dusting of finish surfaces with dry materials will not be permitted.

(1) Monolithic Finish

Surfaces to have monolithic finish shall be finished by tamping the concrete with special tools to force the coarse aggregate away from the surface, and then screeding and floating with straightedges to bring the surface to the required finish level. While the concrete is still green, but sufficiently hardened to bear a man's weight without deep imprint, it shall be floated either by hand or mechanical means to a true, even plane with no coarse aggregate visible. Sufficient pressure shall be used on the floats to bring moisture to the surface. After surface moisture has disappeared, the surfaces shall be machine troweled to a smooth even finish. Trowel marks shall be removed by hand steel troweling.

(2) Rough Slab Finish

Surfaces to receive fill and/or mortar setting beds shall be finished by tamping the concrete with special tools to force the coarse aggregate away from the surface, and screeding with special tools to force the coarse aggregate away from the surface, and screeding with straightedges to bring the surface to the required level.

(3) Broomed Finish

Surfaces to have monolithic broomed finish shall be finished as specified for monolithic finish except that the hand steel troweling be omitted. After the machine troweling is completed, the surface shall be broomed with a fiber bristle brush or broom in a direction perpendicular to the main line of traffic.

(4) Abrasive Finish

Surfaces to have abrasive monolithic finish shall be finished as specified for monolithic finish except that before the steel troweling is commenced an abrasive material shall be evenly applied to the surface at a rate of not less than 1/4-pound (0.1 kg) of abrasive material to each square foot of surface. The surfaces shall then be steel troweled as specified for monolithic finish. The abrasive material shall be aluminum oxide so graded that 100 percent of the particles are retained on a No.30 sieve and 100 percent will pass a No.12 sieve, or other similar product.

2.3.20 Cutting and Patching

All cutting shall be neatly done and shall only be done in areas where the structural quality of the member will not be endangered. Permission shall be obtained from the Engineer prior to any cutting or channeling.

For large openings, a saw equipped with an abrasive disk capable of cutting hardened concrete shall be used to circumscribe the area to be opened. The cut shall be made to a minimum depth of one-half (1/2) inch (12.7 mm) on the outside face of walls or top of slabs.

The inner surface of the opening shall be trimmed of all projections to provide an even, but not smooth, surface.

For smaller openings, a portable core-drilling machine or a star drill shall be employed to cut the hole.

Care shall be exercised as the instrument nears the far face of the concrete so the spalling may be held to a minimum. Patching shall be done with the same type and brand of cement and aggregate as was used in the structure. Forms shall be placed on each side of the larger openings and on only one side of the smaller openings.

A wire brush shall be used to remove foreign substance and loose material from the surfaces of the hardened concrete and a slush coat of non-shrink grout shall be painted over the area prior to placing the concrete.

The openings shall be carefully filled with a 1:3 cement and aggregate mortar with enough water to provide a workable mix. No lime or plaster shall be mixed with this filling mortar.

After the areas have been filled and finished and while the concrete is still green, a final coating of cement and water shall be brushed and rubbed into the concrete.

2.3.21 Curing

(a) General

In general, all concrete surfaces shall be cured and curing shall be accomplished by preventing loss of moisture, rapid temperature change and mechanical injury, or injury form rain or flowing water for a period of seven days. Curing shall be started as soon as free water has disappeared from the surface of the concrete after placing and finishing.

Curing of formed under-surface of beams, girders, floor slabs and other similar undersurfaces, shall be accomplished by moist curing with forms in place for the full curing period, or, if the forms are removed prior to the end of the curing period, by other approved means.

(b) Wet Coverings

Unformed surfaces shall be covered with burlap, cotton, or other approved fabric mats kept in intimate contact with the surface, or with sand and dirt and shall be kept continually wet. Where formed surfaces are cured in the forms, the forms shall be kept continually wet. Burlap shall be used only on surfaces that will be unexposed in the finished work and it shall be in two layers. In extremely hot, windy weather, sunshades, windbreakers and fog nozzles shall be used during flat slab finishing operations.

(c) Waterproof Membrane Coverings

Surfaces may be covered with waterproof paper of with plastic sheets lapped four (4) inches (10 cm) at edges and ends, and sealed with mastic or pressure-sensitive tape not less than 1-1/2 inches (38 mm) wide. The membrane shall be weighted to prevent displacement, and tears and holes appearing during the curing period shall be repaired by patching.

(d) Membrane-forming curing compounds shall be one coat of a sodium silicate liquid floor hardener and shall be applied according to manufacturer's instructions. Surfaces damaged by subsequent construction operations within the curing period shall be resprayed at the rate specified above. Membrane curing compound shall not be used on surfaces that are to receive bituminous membrane, or other damp proofing adhesive for application of other material, concrete fill nor on surfaces that are to be painted. Surfaces coated with curing compound shall be kept free of foot and vehicular traffic and other sources of abrasion during the curing period.

2.3.22 Defective Concrete

Any concrete which shall be found defective from any cause shall be cut out and replaced, and the cost of such cutting and replacing (including disposal of defective, trimmed or left over concrete) shall be borne by the Contractor.

2.3.23 Joints

Joints shall not vary more than 1/4-inch (6.4 mm) from a true line or from their designated position.

(a) Expansion joints shall be so constructed that reinforced corner protection angles, or other fixed metal items, embedded in or bonded into the concrete, shall not be continuous through the joint. Premolded expansion joint filler strips shall be 3/4 inch (19 mm) thick and shall be the full depth of the slab. Premolded expansion joint material shall be preformed strips which have been formed from cane or other suitable fibers of a cellular nature, securely bound together and uniformly saturated with a suitable bituminous binder; or strips which have been formed form clean granulated cork particles securely bound together by a suitable bituminous binder and encased between two layers of bituminous saturated felt and all meeting the requirements of ASTM D1751-83 for "Preformed Expansion Joint Filler for Concrete Paving and Structural Construction", or equal. For expansion joints receiving joint compound the premolded expansion joint filler strip shall be installed below the finished floor with a slightly tapered dressed and oiled wood strip temporarily secured to the top thereof. The wood strip shall be of sufficient depth to form a groove not less than 1/2 inch deep. After the concrete has set the wood strip shall be removed and the joint shall be filled with a hot poured joint sealer. Joint grooves shall be filled approximately flush so as to be slightly concave after drying. Edges of concrete slabs along expansion joints shall be neatly finished with a slightly rounded edging tool.

(b) Construction joints shall not exceed 60 feet (18.3 m) in any horizontal direction unless authorized by the Engineer. Concrete shall be placed continuously so that the unit will be monolithic in construction. At least 48 hours shall elapse between the casting of adjoining units. Construction joints, when required shall be located near the midpoint of spans for beams or girders unless a beam intersects a girder at the center in which case the joints in the girder shall be offset a distance equal to twice the width of the beam and provision for shear shall be made by use of inclined reinforcement. Joints in columns shall be made at the underside of the deepest beams or girder framing thereto. Columns or walls of ordinary height shall be poured at least two hours before any overhead work is placed thereon. Joints not specified shall be so located as to least impair the strength and appearance of the work. Construction joints in wall footings shall be reduced to a minimum. Except where otherwise indicated no jointing shall be made in footings or foundation work without the approval of the Engineer's Representative. Placement of concrete shall be at such rate that surfaces of concrete not carried at joint levels will not have attained initial set before additional concrete is placed thereon. Girders, beams and slabs shall be placed in one operation. A strip of dressed lumber shall be tacked to the inside of the forms at the construction joint.

(c) Caulked joints shall be constructed at the junction of concrete walls, and walls to slabs.

2.3.24 Grout

Grout shall be used for precast units for bedding machinery pads, posts, spouts, conduits, columns and other structural members that are to bear on concrete.

Non-shrink grout shall be used for seating, leveling and bedding precast concrete and structural steel members, machinery supports and other embedded items where intimate contact may be obtained by pressure and where the requisites of non-shrink grout are not required.

2.3.25 Reinforcing Steel

Reinforcing steel shall be as shown on the drawings for sizes, shapes, dimensions and placement. The Contractor shall submit detailed bar lists, bending schedules and drawings to the Engineer for approval.

The reinforcement shall consist of high or low tensile steel that conforms to Norms EN 10080:2005 “Steel for the reinforcement of concrete. Weldable reinforcing steel. General”, EU-8069 and EU-8085. The Engineer retains the right to demand from the Contractor to present certificates of quality control from the supplier. The steel bars bending shall be carried according to Norm EN 10080.

The reinforcement bars must be clean, free of impurities, dust, oil and paint. The reinforcement must be placed and mantled with precision according to the drawings. Where it is not specified the concrete cover is set to 25 mm.

The reinforcement lap length will be at least 50 times the diameter bars unless otherwise specified in the drawings.

The reinforcement must be supported adequately so as not to deform and be able to carry loads during concreting. In order to ensure the appropriate cover concrete, plastic or other spacers approved by the Engineer must be used.

The overlapped bars will not be welded unless in specific cases approved by the Engineer. In the above mentioned cases the bars will be welded according to standards EN 1011-1:1998 “Welding. Recommendations for welding of metallic materials. General guidance for arc welding”, EN 1011-2:2001 “Welding recommendations for welding of metallic materials. Arc welding of ferritic steels” and EN 60974:2002 “Arc welding equipment” and IEC 60974-12:2005 “Arc welding equipment: Coupling devices for welding cables”.

2.3.26 Temperature, Wind and Humidity

(a) Cold Weather

When the air daily outdoor temperature is less than 5°C (40°F), the temperature of the concrete shall be maintained between 10°C and 20°C (50°F and 70°F) for the required curing period. When necessary, arrangements for heating, covering, work shall be made in advance of placement and shall be adequate to maintain the required temperature without injury due to concentration of heat. Concreting in cold weather shall be in accordance with ACI-304, or equal.

(b) Hot Weather

The Contractor shall be adequately prepared to protect the concrete from the adverse influence of hot weather before the placement of any concrete may begin. Placement of concrete when the air temperature exceeds 20°C (70°F), particularly when the work is exposed to direct sunlight, shall be done taking special precautions to avoid cracking of the concrete from rapid drying.

Forms, particularly metal forms, shall be cooled by sprinkling with water or by protecting them from direct rays of the sun. The temperature of the forms shall not exceed 38°C (100°F).

If requested by the Contractor, and approved by the Engineer, a retardant may be used to delay the initial set of the concrete.

Concrete shall be placed at a sufficient rate so that cold joints are not formed by the rapid set of concrete. Moist curing shall be applied as soon as possible after placement to inhibit the development of shrinkage cracks due to the rapid drying of the surface.

Concreting in hot weather shall be in accordance with ACI-304, or ACI 305R-10.

(c) Rate of Temperature Change

Changes in temperature of the air immediately adjacent to the concrete during and immediately following the curing period shall be kept as uniform as possible and shall not exceed 3°C (5°F) in any one(1) hour or 30°C (50°F) in any twenty-four (24) hour period.

2.3.27 Protection from Mechanical Injury

During the curing period, the concrete shall be protected from damaging mechanical disturbances, such as load stresses, heavy shock, and excessive vibration. All finished concrete surfaces shall be protected from damage by construction equipment, materials or methods, by applications of curing procedures, and by rain or running water.

Self-supporting structures shall not be loaded in such a way as to over-stress the concrete.

2.4 CONCRETE LINING WORKS

2.4.1 General

(a) Cement conforms to the specifications of "Materials" in Concrete Works.
This clause applies to concrete lining canal construction.
(b) Relevant specifications conform to the "2.2. Earth Works" and "2.3. Concrete Works" specifications.
(c) Prior to lining concrete work, a work plan must be submitted to the Engineer for approval.

2.4.2 Materials

(a) Cement conforms to the specifications of "Materials" in Concrete Works.
(b) Reinforcing bars conform to the specifications of "Structural Steel Works" in "Materials".
(c) Sand and Aggregate conform to the specifications of "Materials" in Concrete Works.

2.4.3 Earth Cutting and Filling

(a) Cement conforms to the specifications of "Materials" in Concrete Works.
(b) Earth cutting and filling for concrete lining works conform to "2.2. Earth Works" specifications
(c) If the local geotechnical conditions after earth cutting are different from the design conditions, consult with the Engineer.
(d) If the depth of the earth cutting is deep, consideration should be given to the condition of the soil and necessary measures should be taken to prevent safety accidents due to slope collapse.
(e) The temporary drainage facilities in the canal shall have sufficient sizes such that the rainfall and leaked water shall not be stagnated in the waterway during the lining construction, and shall not cause slope failure and ground softening.
(f) Prior to the concrete lining, the surface condition of the canal must be confirmed by the Engineer.
(g) Prior to earth filling, remove the topsoil, such as organic soil, so that the ground and the soil deposited are well bonded.
(h) Where the water is flooded, it must be completely drained and dried before the earth filling.
(i) The earth used for earth filling should be excavated soil. However, it is necessary to consult with the Engineer if it is necessary to replace with high quality soil because it contains harmful substances such as stones, gravel and organic matters.
(j) Do not use excavated soil with high water content to earth filling.
(k) Compaction for concrete lining conforms to the specifications of "2.2. Earth Works"
(l) In order to ensure the degree of compaction specified in the design drawing, the type of equipment, layer thickness, number of times of compaction, etc. should be determined and the soil compaction should be made accordingly.
(m) Where compaction using large machinery is difficult, sufficient compaction should be performed using manpower compaction and vibration compaction.
(n) Where there is water leaking on the ground or there is a risk of sliding, consult the Engineer and follow his instructions.

2.4.4 Concrete Lining Construction

(a) Concrete lining work conforms to the “2.2. Earth Works” specifications.
(b) Canal concrete lining work is to be done using lining machines, and lining work of mountain ridge drainage canals should be done by manpower.
(c) In lining work, the frame rule should be installed at appropriate intervals so that it can be inspected whether the construction is done as specified in the design, and the slope concrete lining should be installed from the bottom of the canal to the top.
(d) Canal concrete lining work should be applied to the 1/2 section from the center line of the canal section. Adjacent sections should be constructed at least 14 days later.
(e) Wire mesh shall be installed at 1/4 of the lining thickness from the concrete lining

surface.
(f) Lining concrete must be sufficiently compacted and the surface to be finished smoothly.

2.4.5 Concrete Joints

(a) Concrete lining work conforms to the “2.2. Earth Works” specifications.
(b) Vertical joints of lining concrete shall be installed every 6 m, and the horizontal joints and work joints shall be installed along the centerline of the canal section.
(c) The position of the work joint in the transverse direction shall be the same as the position of the expansion joint.
(d) The joints shall be correctly installed at the locations shown in the drawings and shall not be deformed during concrete works.
(e) Concrete cutting shall be carried out as soon as possible within the extent that the concrete surface is not damaged, so that the initial cracks are induced in advance.
(f) The joint filling material shall be injected in the dry condition of the concrete after two weeks, at which the alkaline component generated during the curing of the concrete disappears.
(g) Apply the primer to the concrete cut surface twice, and then insert the backup material first and sealant next.
(h) The backup material should have the same insertion depth and should be 25-35% thicker than the joint width.

2.5 CONCRETE FLUME, DROP STRUCTURE, SIPHON WORKS

2.5.1 General

(a) This clause applies to Concrete Flume, Drop Structures and Siphon Works.
(b) Relevant specifications conform to the "2.2. Earth Works" and "Concrete Works" specifications.
(c) When Siphon passes through the river, consult with the Engineer to discuss the construction location, construction order and construction method.
(d) If there is a concern about negative pressure due to an increase in the outside water level during the flood, consult with the Engineer to establish a countermeasure for lowering the outside water level and then construct it.

2.5.2 Materials

(a) This clause applies to Concrete Flume, Drop Structures and Siphon Works.
(b) Cement shall conform to the specifications of "Materials" in Concrete Works.
(c) Reinforcing bars conform to the specifications of "Structural Steel Works" in "Materials".
(d) Sand and Aggregate conform to the specifications of "Materials" in Concrete Works.

2.5.3 Earth Cutting

(a) This clause applies to Concrete Flume, Drop Structures and Siphon Works.
(b) Relevant specifications conform to the "2.2. Earth Works " specifications.
(c) If the local geotechnical conditions after earth cutting are different from the design conditions, consult with the Engineer.
(d) If the depth of soil cutting is deep, take appropriate measures, such as cutting the soil with a safe slope to avoid slope failure taking into account the soil condition.
(e) The earth cutting shall be of a depth specified in the design book and shall be wide enough to allow the work of the formwork and concrete works.
(f) Where the foundation is weak, appropriate reinforcement methods shall be applied in consultation with the Engineer.
(g) The earth cutting must be carried out in a dry condition with adequate drainage, and the foundation of the structure should always be dry after earth cutting has been completed.
(h) Foundation grounds shall be earth-cut and inspected by the Engineer in accordance with the dimensions and elevation before blinding concrete or foundation laying.
(i) The remaining soil must be transported to the site designated by the Design Book or the Engineer and treated so as not to cause damage such as erosion or burial.
(j) When the finished foundation is a clay layer, measures should be taken to prevent excessive drying.

2.5.4 Concrete Placing

(a) This clause applies to Concrete Flume, Drop Structures and Siphon Works.
(b) Relevant specifications conform to the “Concrete Works”, “Form Works” and “Building Works - Reinforcement” specifications.
(c) The Transition part is to work on concrete simultaneously with the Siphon body.
(d) Siphon sidewalls shall be constructed after the siphon floor slab has settled, and the connections between the sidewall and floor shall be roughened to ensure good adhesion, and a copper water stop plate should be installed at the joint.
(e) If the height of the siphon is more than 1.2 m, the upper slab concrete should be placed after the side wall concrete has hardened.
(f) The position of the work joint in the transverse direction shall be the same as the position of the contraction joint or expansion joint.
(g) The water stop plate, expansion joint plate and dowel bar shall be correctly installed at the joints at the locations indicated in the drawings and shall not be moved when concrete placing.
(h) Joints shall be watertight as well as structural safety.

2.5.5 Backfilling

(a) This clause applies to Concrete Flume, Drop Structures and Siphon Works.
(b) Relevant specifications conform to the "2.2. Earth Works" specifications.
(c) Backfilling should be done after the concrete has reached adequate strength and should be consulted with the Engineer.
(d) The earth used for earth filling should be excavated soil. However, it is necessary to consult with the Engineer if it is necessary to replace with high quality soil because it contains harmful substances such as stones, gravel and organic matters.
(e) Do not use excavated soil with high water content to earth filling.
(f) In order to ensure the degree of compaction specified in the design drawing, the type

of equipment, layer thickness, number of times of compaction, etc. should be determined and the soil compaction should be made accordingly. If not specified, the density should be greater than the density of the natural state.

(g) During backfilling and compaction work up to 60 cm above the Siphon body, care should be taken not to place a concentrated load on the siphon barrel, and compaction by a large machine such as a roller or bulldozer is not allowed.

(h) The backfilled surface shall be in harmony with the surrounding ground.

(i) The upstream part of drop structures the canal embankment could be lowered due to rainfall erosion and there is a risk of overflow. Therefore, the corresponding section should be increased.

(j) The downstream part of the drop structures shall be sufficiently protected with a barrier wall, floor protection, etc. to prevent scouring, breakage, etc. before connected to the downstream channel.

(k) In the connection with the transition or lining channel at both ends of the siphon, measures should be taken to prevent penetration passages due to sinking of channel, poor compaction, and scouring.

2.5.6 Subsidiary Facilities and Safety Facilities

(a) This clause applies to Concrete Flume, Drop Structures and Siphon Works.

(b) Siphon mud valves, manholes, air valves, drain pipes, etc. shall be installed in the locations indicated in the design drawing.

(c) The drain pipe of the mud valves starting from the Siphon drain valve or drainage outlet shall be connected to the nearest drain channel or drainage point indicated by the Engineer.

(d) All subsidiary facilities shall be constructed of materials and shapes specified in the design drawing or technical specifications.

(e) A safety fence, such as a barrier fence, should be installed in the entrance and exit of the siphon to prevent people or animals from falling into the canal and safety accidents.

(f) Measures should be taken to prevent overflow at the entrance of due to accumulation of garbage and obstruction of water flow.

2.5.7 Leakage Test

(a) This clause applies to Concrete Flume, Drop Structures and Siphon Works.

(b) Siphon should be backfilled after leakage test before normal operation.

(c) The leakage testing procedures and methods shall be in accordance with the relevant regulations.

2.6 STRUCTURAL STEEL WORKS

2.6.1 General

This section covers all structural steel work. Whenever a difference exists between the design drawings and this specification, the drawing shall govern.

(a) Structural steel consists of the steel work for buildings, structures and pipe supports.

Structural steel also consists of steel work for the framing of bridge connections between structures and for equipment inside and outside the building as required.

(b) Specification : Unless otherwise indicated, the "Specification for structural steel buildings" of the American Institute of steel construction, adopted June 1, 1989 or approved equal, shall govern the work.

2.6.2 Reference Standards

Reference Standards are referred to in the follows.

ASTM A36	Standard Specification for Carbon Structural Steel
ASTM A307	Standard Specification for Carbon Steel Bolts and Studs, 60 000 PSI Tensile Strength
ASTM A325b	Standard Specification for Structural Bolts, Steel, Heat Treated, 120/105 ksi Minimum Tensile Strength
ASTM A325Mb	Standard Specification for Structural Bolts, Steel, Heat Treated 830 MPa Minimum Tensile Strength [Metric]
ASTM A502-65	Standard Specification for Rivets, Steel, Structural
ASTM F844	Standard Specification for Washers, Steel, Plain (Flat), Unhardened for General Use

2.6.3 Materials

(a) Structural steel : All structural steel shall conform to ASTM A36 specification or equal.

(b) Bolts and Nuts

- Common bolts shall be 3/4 inch (19 mm) diameter unless otherwise noted, and shall conform to ASTM A307 or equal.
- High-Strength bolts shall be 3/4 inch (19 mm) diameter unless otherwise noted, and shall conform to ASTM A325 or equal. One high-strength bolt assembly shall consist of a heavy semi finished hex head structural bolt and a heavy semi-finished hex nut.
- Rivets shall conform to ASTM A502-65 for "steel structural rivet" or equal.
- Washers : Round washers shall conform to ASTM F844 "plain washers" or equal. Beveled washers shall be square, smooth, and sloped so that contact surfaces of bolt head and nut are parallel. The diameter of the hole of square-beveled washers shall be 1/16 inch (1.6 mm) greater than the bolt size for bolts not larger than one (1) inch (25.4 mm) and 1/8 inch (3.2 mm) greater than the bolt size for bolts larger than one (1) inch (25.4 mm).

2.6.4 Shop Details and Fabrication

(a) The Contractor shall conform to the following shop detail drawings and fabrication requirements unless shown otherwise on drawings.

- All connections which are not detailed or otherwise noted on drawings shall be shop welded and field-bolted AISC Framed Beam connectors, Table III and I. Use the maximum number of rows of Table I for each beam depth use a 1/4 inch (6.4 mm) shop weld "A" shown in Table III for the required number of field bolts.

- Bolts for field connection shall be high-strength bolts in bearing connections unless otherwise noted on drawings. Do not omit paint or galvanizing from the contact surfaces within the joints. Bolt threads need not be excluded from the shear planes.
- End distances shall conform to AISC Specification for Structural steel buildings section J 3.10 without reduction to low stresses, unless otherwise noted on drawings.
- The contractor shall furnish and install erection clips for fit-up of welded connection.
- Ample clearance shall be provided for field erection.
- Double angle members shall have welded fillers spaced in accordance with section E4 of the AISC Specification.
- Gusset plates shall be 1/4 (0.25) inch (6.4 mm) thick minimum.
- Columns have full bearing at splices and at end plates.
- All sharp corners and burrs shall be removed before shop priming.
- Floor plate shall be furnished where indicated on the drawing.
  - Floor plate shall be skid resistant raised pattern plate, 1/4 inch (6.4 mm) thick excluding the height of the raised pattern.
  - Floor plates shall be secured in place by intermittent welding of plate to support beams.
  - Continuous plates shall be plug welded to intermediate support beams.

2.6.5 Welding

Welding shall be in accordance with the American welding society code D1.1-69 "welding in building construction", and code D12.1-61, "Recommended practices for welding reinforcing steel, metal inserts and connections in reinforced concrete construction", or equal.

2.6.6 Qualification of Welders

Before assigning any welder to work covered by this section of the specifications, the contractor shall provide the Engineer with the names of the welders to be employed on the work, together with certification that each of these welders has passed qualification tests using procedures covered in the American welding society standard B3.0, or equal. The contractor shall require any welder to retake the test when, in the option of the Engineer, the work of the welder creates a reasonable doubt as to the proficiency of the welder. Tests, when required, shall be made at the expense of the contractor. Re-certification of the welder shall be made to the Engineer only after the welder has taken and passed the required retest. Welders shall have passed the qualification tests within the preceding 12-months period.

2.6.7 Shop Drawings and Erection Procedures

Shop drawings shall be submitted for approval. Drawing shall show the size, length, and type of each weld. Along with the shop drawings, the contractor shall furnish two copies of detailed erection procedure, including sequence of erection and temporary staging and bracing. Approval of shop drawings shall be interpreted as approval of general methods and arrangement only, and shall not constitute verification of dimensions or quantities. The contractor shall be responsible for the accuracy of fabrication and erection fit-up.

2.6.8 Piece Marking

(a) Each shipping piece shall be clearly marked. The location of the mark shall be on the left-hand end of the piece as detailed. On the erection drawing the mark shall be in corresponding in-place position.

(b) The pipe support number, as shown on the design drawings, shall be a part of the piece-marking on all supports.

2.6.9 Fabrication

Structural steel shall be fabricated and assembled in the shop to the greatest extent possible. Shearing, flame cutting, and chipping shall be done carefully and accurately. Sole plates of beams shall have full contact with the flanges. Fillers under end angles shall not project beyond the back of the angles. Clearance between the ends of spliced web plates shall not exceed 1/4 inch (6.4 mm) where riveting occur near welded joints; the welding shall precede the riveting unless otherwise approved. Assembled pieces shall be taken apart if necessary for the removal of burrs and shavings produced by the reaming operation. Parts not completely riveted in the shop shall be secured by bolts, insofar a practicable, to prevent damage in shipment and erection.

(a) Connections : Shop and field connections may be either riveted, bolted or welded. One-sided or other types of eccentric connections will not be permitted unless shown in detail and approved on the shop drawings. Combinations of rivets and unfinished bolts shall not be used in the same face of any connection. Unfinished bolts shall not be used except where required. Surfaces of joints for riveted or welded connections shall comply with the cleanliness requirements of all joint surfaces and contact surfaces within friction-type joints as outlined in the AISC specifications for structural joints using ASTM A325 bolts, or equal.

(b) Holes shall be cut, drilled, or punched at right angles to the surface of the metal and shall not be made or enlarged by burning. Holes n base or bearing plates shall be provided in members to permit connecting the work of other trades. Holes shall be clean-cut without torn or ragged edges. Outside burrs resulting from reaming or drilling operation shall be removed by a tool making a 1/16 inch (1.6 mm) bevel.

(c) Allowance shall be made for draw in all tension bracing.

(d) Riveting : Rivet heads shall not be caulked, recouped, or double-gunned. In removing defective rivets care shall be taken not to injure the adjacent metal and, if necessary, rivets shall be drilled out. Rivets less than 1/2 inch (12.7 mm) in diameter may be driven cold if approved measures are taken to prevent distortion of the riveted material. When ready for driving, rivets shall be free from slag, scale, and other adhering matter.

(e) Bolts shall be driven accurately into the holes without damaging the thread. Bolt heads shall be protected from damage during driving. Bolt heads and nuts shall rest squarely against the metal. Where bolts are used on beveled surfaces having slopes greater than one in 20 with a plane normal to the bolt axis, beveled washers shall be provided to given full bearing to the head or nut. Where self-locking nuts are not furnished, bolt threads shall be upset to prevent the nuts from backing off. Unfinished bolts transmitting shear shall be treaded to such a length that not more than one thread will be within the grip of the metal. The bolts shall be of the length that will extend entirely through but not more than 1/4 inch (6.4 mm) beyond the nuts. Bolts heads and nut shall be drawn tight against the work with a suitable wrench not less than 15 inches (0.38 m) long. Bolt heads shall be tapped with a hammer while the nut is being tightened. After having been fully tightened, nuts shall be locked.

(f) Welding shall be accordance with the American Welding Society code D1.1-69, "welding in building construction", and code D12.1-61, "recommended practices for welding reinforcing steel, metal inserts and connections in reinforced concrete construction", or equal. All shop welds performed on the main supporting members of the equipment which are subjected to high stress shall be 100 percent X-ray tested. In addition, the Engineer may require other shop and field welds to be X-ray tested. The photographs of all these tests shall be submitted to the engineer thru the Engineer's Representative. The cost of all X-ray test shall be charged to by the contractor.

2.6.10 Erection

Splices and field connection shall be made with high-strength bolts. Welding will be permitted only where shown and approved on the shop drawings. Errors in shop fabrication or deformation resulting from handling and transportation that prevent the proper assembly and fitting of parts shall be corrected as approved or replaced with new materials.

(a) Anchor bolts and anchors shall be properly located and built into connection work. Bolts and anchors shall be preset by the use of templates.

(b) Base plates, and bearing plates shall be provided under columns and bearing plates may be attached or loose as approved on the shop drawings. Base plates and bearing plates shall be supported and aligned on steel wedges or shims. After the supported members have been plumbed and properly positioned and the anchor nuts tightened, the entire bearing area under the plate shall be dry-packed solid with non-shrink grout complying with “2.3.8 Grout” specified in "2.3 Concrete Works”. Wedges and shims shall be cut off flush with the bearing plate, and shall be left in place.

(c) Assembly : The various members forming parts of a completed frame or structure shall be aligned and adjusted accurately before being fastened. Tolerances shall conform to AISC Code of Standard Practice, or equal. Fastening of splices and compression members shall be done after the abutting surfaces have been brought completely in contact.

(d) Bearing surfaces and surfaces that will be in permanent contact shall be cleaned before the members are assembled. As erection progress, the work shall be securely fastened to take care of all dead load, wind, and erection stresses. Splices shall be permitted only when approved. Unless removal is required to continue erection, all erection bolts used in welded construction may be tightened securely and left in place. If erection bolts are removed, the holes shall be filled with plug welds. Welding for re-drilling will not be permitted.

(e) Drift pins may be used only to bring together the several parts and shall not be used in such a manner as to distort or damage the metal.

(f) Gas cutting : The use of a gas cutting torch in the field for correcting fabrication errors will not be permitted on any major member in structural framing. Gas cutting will be permitted on minor members when the member is not under stress, and then only with the approval of the Engineer's Representative.

2.6.11 Damaged Members

Use of members damaged during transportation will be permitted only as approved by the Engineer and the Engineer's Representative. Methods of repairing damaged members must be submitted to an approved by the Engineer or the Engineer's Representative prior to undertaking such work.

Test of repaired members shall be required as deemed appropriate or necessary by the Engineer and the Engineer's Representative. Unfavorable results of such tests shall be cause for rejection.

2.6.12 Inspection and Tests

The material to be furnished shall be subject to inspection and tests in the mill, shop, and field. However, inspection in the shop or mill will not relieve the contractor of the responsibility to furnish satisfactory materials.

2.6.13 Defective Members

Any steel members which shall be found defective from any cause shall be cut out and replaced, and the cost of such cutting and replacing (including disposal of defective or cut off members) shall be borne by the Contractor.

2.7 PIPELINE WORKS

2.7.1 General

(a) Method Statement

- This specification applies to the laying of concrete pipelines, ductile cast iron pipeline, steel pipeline, vinyl chloride pipeline, polyethylene pipeline, etc.
- For matters not stipulated in this specification, the design and construction specifications should be followed.

(b) Reference Standards of Steel Pipes

- Carbon steel pipes for ordinary Piping: KS D 3507, JIS G3452, ASTM A53, API 5L, DIN 2440 & 2441, BS 1387 & 3601
- Carbon steel pipes for pressure service: KS D 3562, JIS G3454, ASTM A53, DIN 1626 & 1628 & 1629 & 1630, BS 3601 & 778
- Coated steel pipes for water works: KS D 3565, ASTM A252, ASTM A53, ASTM A500, EN 10210, EN 10219, API 5L, DIN 1626/1615, DIN 17120
- Fittings of coated steel pipes for water works: KS D 3578, AWWA C200 & C203
- Arc welded carbon steel pipes: KS D 3583, JIS G3454, ASTM A134 & A139 & A671 & A672

(c) Reference Standards of HDPE Pipes

- Plastics piping systems for water supply, and for drainage and sewerage under pressure Polyethylene (PE): KS M 3408, ISO 4427-2:2019
- Standard Specification for PE (PE) Plastic Pipe: ASTM D 2447, ASTM D 3035, ASTM F 714, ASTM D 2104, ASTM D 2239
- EN 12201:2003 "Plastics piping systems for water supply - Polyethylene (PE)"
- DIN 8074 "Polyethylene (PE) Pipes Dimensions"
- DIN 8075 "Polyethylene (PE) Pipes General Quality Requirements and Testing"
- DIN 19533 "PE HD/LD pressure pipes for water supply, requirements"
- DIN 16963 "Pipe Joint Assemblies and Fittings for High - Density Polyethylene (PE-HD) Pressure Pipes"
- EN 13244:2002 "Plastics piping systems for buried and above-ground pressure systems for water for general purposes, drainage and sewerage. Polyethylene (PE)".

(d) Quality assurance

- In order to ensure that the construction has the specified quality, the quality control of suppliers, manufacturers, products, services, site conditions and construction should be monitored.
- Installation work should follow the manufacturer's instructions.
- If the manufacturer's manual does not match the contract document, it should be reviewed by the supervisor before starting. commencement of works.
- Specified specifications should be kept to at least the designated lower level or more, unless tighter tolerances, regulations, or specified requirements are specified for higher specifications or more precise construction.
- The work should be carried out by qualified persons capable of achieving the required and specified quality.
- The on-site inspection should be confirmed and confirmed as specified in the detailed construction drawings or as directed by the manufacturer.
- The product should be designed to withstand stress, vibration, torsion or depression and held in place with anchorages of sufficient dimensions.

(e) Transport

- When loading and unloading pipes and accessories, do not give impact to the pipes by throwing or pulling them down. In particular, both ends of the pipe, joints, and painted or coated parts clothing should be protected as necessary so as not to be damaged, and care should be taken in handling.
- In the case of transport of pipes and accessories, in order to avoid contact with each other or with the vehicle body due to the shaking of the body, the pipes should be protected with rubber sheets, straw mats bulkheads, etc., and fixed with wedges, ropes, etc. at the same time.

(f) Storage of materials

- In case the pipes need to be stacked in the same place during construction, a flat place topography should be selected to prevent the pipes from falling. In addition, when stacking in layers, the pipe diameter of 500 mm or less should be stacked within 1.5 m in height (1.0 m for rigid unplasticized poly vinyl chloride pipes), and the pipe diameters of 600 to 1,000 mm should be stacked in two layers, and more than that in one layer.

- For the storage of pipes at the accumulation site, use struts a field bed to prevent subsidence of the pipe body and grounding of joints, and when stacking in stages, it should be secured with wedges or tied with ropes to prevent collapse. When storing for a long time, cover it with a sheet, etc.
- Iron pipes such as steel pipes and cast iron pipes and their accessories should be stored so that they do not get wet, do not rust, and are not deformed under load.
- Vinyl chloride pipes and polyethylene pipes should not be crushed or damaged by heat or load, and should be stored out of direct sunlight, and should be especially safe from fire.

(g) Quality management

- Tests of various pipes should be carried out according to the relevant international standards, and even in the case of the same type of pipe, the test should be conducted whenever the standard changes and in the type and frequency specified in the construction specification.

2.7.2 Construction

(a) Earthworks

- General matters concerning excavation should follow “2.2 Earthworks”.
- If the local ground condition after excavation is different from the design condition, the construction inspector (or supervisor) should be consulted.
- In the case of a deep excavation, necessary measures should be taken to prevent a safety accident due to the collapse of the slope in consideration of the soil condition.
- The excavation should be made at the depth specified in the design document, and the characteristics according to the type of foundation should be considered.
- The construction tolerance according to the excavation of the pipeline is as follows.
  - i) Soil : ±10cm
  - ii) Ripping rock: ±20cm
  - iii) Blasting rock: ±30cm
  - iv) Concave and convex of soil and road surface: ±5cm or less
  - (v) Concave and convex surface of ripping arm and blasting arm: ±15cm or less
- The construction tolerance for the elevation of the drawing specified in the excavation shall be within ±30mm.
- For excavation, the necessary width and slope should be secured in consideration of the pipe laying, jointing, foundation work, refilling backfilling, etc. and the safety of the pipe body, and over-excavation should be avoided as much as possible.
- When excavating a site adjacent to an existing structure, sufficient protection treatments should are to be installed so that the foundation of the existing structure does not loosen or pose a danger.

- If an underground facility is found in the place where there is an underground facility or during excavation work, report it to the construction inspector (or supervisor), notify the manager of the underground facility, and perform construction without damaging to the underground facility. However, if it is necessary to change the pipe line due to an underground facility, consultation with the construction inspector (or supervisor) is required.
- In general, the width of the trench for burying the polyethylene pipe should be at least 7.5 to 10 cm on both sides of the pipe to install the filter material. If it is wide, measures to protect the pipe are required, so the slope of the excavation slope should be cut as steep as possible so that the lateral bearing capacity of the pipe is not reduced.
- Residual soil should be transported to a place designated by the design document or the construction inspector (or supervisor) and treated to prevent damage such as erosion or burial.
- The condition of the foundation ground after excavation is completed should be confirmed by the construction inspector (or supervisor).

(b) Backfilling

- General matters concerning excavation should follow “2.2 Earthworks”.
- Backfilling should be done so that the pipe body does not move due to unbalanced pressure applied to it.
- Backfilling should be proceeded in parallel with the joining of the pipes. Backfilling to a depth of about 60 cm above the top of the pipe should be carried out quickly after joining the pipe. However, in the case of a water-through test, backfilling is carried out in consideration of the water-through test.
- Anything that interferes with the structure of the pipe and the pipe body, such as the strut used when installing the pipe, should be removed prior to backfilling.
- For backfilling, the type of equipment, thickness of the compaction layer, number of compactions, etc. should be determined and compacted so that the degree of compaction specified in the design document is secured. . If not specified, it should be compacted more than the density of the natural state (original ground). In particular, when backfilling refilling and compacting up to 60cm above the top of the pipe, be careful not to apply unbalanced pressure to the pipe, and compaction with large machines such as rollers and bulldozers is prohibited.
- Be careful not to create voids or insufficient compaction in the lower part and side of the pipe, and compact the pipe so as not to damage the pipe by using a compactor, rammer, vibrating compactor, or water compaction method.
- Up to 30cm of corrugated polyethylene pipe should be filled with good-quality soil not mixed with gravel. Be careful not to change the position of the pipe after completion. The transverse reverse deformation during backfilling to offset the transverse load of the pipe due to the upper load should be generated in advance by about 3%.
- The filling material around the corrugated polyethylene pipe should be less than 7.5cm of the maximum particle diameter, and there should be no voids around the pipe.

(c) Dewatering or Diversion

- If there is spring water or rainwater during work such as excavation, joint laying of pipes, backfilling, etc., dewatering or diversion is required.

- Dewatering during concrete placing pouring should be continued for at least 24 hours after placing.
- Dewatering should be carried out so that concrete material is not lost.

2.7.3 Foundation

(a) Soil foundation and sand foundation

- The pipe installation part should be excavated according to the design drawings to form the floor foundation, and the entire pipe length should be uniformly supported by leveling the high and low parts and removing stones and gravel. In particular, it is to be ensured that the state in which the vertical load is concentrated does not occur in the joint part of the pipeline.
- In the case of a soil or sand foundation, the pipeline bottom should be sufficiently compacted before pipeline laying and the side observation parts should be sufficiently compacted after laying, taking care to prevent subsidence of the pipeline. The compaction method and degree of compaction follow the design drawings or the instructions of the construction inspector (or supervisor).
- In the case of a sand foundation, the pipeline should be firmly supported so that it adheres to the outer periphery (lower part) of the pipeline, and it should be possible to secure the angle of construction support more than specified in the design. In addition, the thickness of the foundation at the bottom of the pipe should be at least 100~200mm or 0.2~0.25 times the outside diameter of the pipe, and if it is rocky, it should be thicker than this.
- After reciprocating the bottom of the foundation twice or more with a vibrating compactor (impacter), make a foundation of the specified thickness and perform leveling.
- In the ground where the rock protrudes, cut out more than 10cm, fill it with soil or sand, and compact it to support the pipeline.
- In the place where the bedrock and the earthen ground are in contact, the subsidence of the earthen ground should be reviewed and countermeasures should be taken in preparation for the deformation of the pipe according to the subsidence of the earthen ground.
- When constructing a sand foundation on a steep longitudinal slope, especially in the case of a large amount of spring water, consultation with the construction inspector (or supervisor) is required.
- If there is a risk of causing a concentrated load in contact with the pipe due to the presence of rocks or stones in the foundation ground for laying corrugated polyethylene pipeline, the foundation should be made of sand, gravel, silt sand, viscous sand, etc. to prevent concentrated load on the pipe. At this time, the maximum particle diameter of the base material should be 19mm or less.

(b) Concrete foundation

- For the concrete foundation, the pipeline should be temporarily laid in place and the concrete should be sufficiently compacted so that it extends evenly to the outer circumferential surface of the pipe bottom.

- In principle, concrete for the foundation is placed placing at the front end of the foundation at a time, but when the foundation bed is first placed for pipeline installation, and then in the second placing is laid on it, and a pipe is place secondly, care should be taken to ensure that the concrete the upper layer sufficiently fills the pipeline bottom.

2.7.4 Pipeline laying

(a) Installation

- When laying a pipeline, always measure the elevation and length of the pipeline so as not to cause an error in the laying.
- Pipes brought into the site should be arranged along the planned pipelines so that there is no hindrance to the passage of working machines or workers and the laying work is easy.
- In principle, pipeline laying should be done going from the lower part to the upper part, and the pipe with socket should be laid with the socket facing upstream.
- Before laying the pipe, the inner surface of the pipe, especially the joint, etc., should be sufficiently cleaned and inspected for damage.
- Always pay close attention to the handling of small transport, loading, and fixing of pipes, and take necessary measures to prevent accidents such as falls, collisions, and sidewall collapse.
- In principle, adjustments for tolerances in pipe specifications and expansion and contraction occurring during joint construction should be made in a straight section.
- When pipeline laying is to be stopped for a certain period, protective measures such as stoppers should be taken to prevent the inflow of soil, etc.
- If there is a risk of the pipeline floating due to water stagnating in the trench where the excavation was made, appropriate measures such as backfilling at an early stage after laying should be taken to prevent the pipeline from floating.
- If the pipeline is installed in a curve within the allowable bending angle of the pipe joint, in principle, the pipe should be joined in a straight state and then gradually bent to a predetermined angle.
- After joining the pipe, a predetermined inspection is performed to check whether it is appropriate, and the result is reported to the construction inspector (or supervisor), and defective part should be corrected or reconstructed according to the situation.

(b) Pipe cutting

- When it is necessary to cut the pipe, the residual pipe material should be checked compared and fouand used as much as possible.
- When cutting the pipe, the cut length of the pipe and the cut point are precisely determined, and the cut line is marked on the entire circumference of the pipe.
- The pipe cutting should be made at right angles to the pipe axis.
- If there is a combustible material near the place where the pipe is cut, take necessary measures for safety and then proceed with caution.
- The cutting of cast iron pipes is to be carried out as follows:

① In principle, the cast iron pipe is cut with a cutter, and when cut, the cross section of the insertion hole is chamfered with a grinder, etc., and the insertion dimension is marked with a white line.

② For cutting machines that use an engine as a power source, consideration should be given to noise.

③ Variant pipes such as T-shaped socket pipes should not be cut.

④ The cut surfaces of cast iron pipes should be coated with anticorrosive coating without harm to hygiene.

- Steel pipes are to be cut as follows:

① The steel pipe is cut by removing the coating paint with a width of 30cm centered on the cut line and marking the cut line. Also, be careful not to catch fire on the coating paint inside and outside the pipe tube while cutting, and take appropriate protective measures.

② After the steel pipe is cut, the joint should be carefully finished like the shape of the end of the other pipe, and the cut part should be trimmed to the same dimensions as the other pipe.

- The cutting of glass fiber reinforced plastic pipe and rigid unplasticized poly vinyl chloride pipe should be as follows.

① When cutting glass fiber reinforced plastic pipe and rigid unplasticized poly vinyl chloride pipe, mark the cut line so that the pipe axis of the cut surface is at a right angle and then cut.

② The cut surface should be sharpened with sandpaper or the like.

③ The outer surface of the cut surface is chamfered with the same dimensions as the other pipe to facilitate insertion of the connector.

④ After chamfering, mark the insertion depth of the connector, and clean the inside and outside of the pipe.

- Other pipe cutting is as follows.

① When cutting the pipe, draw a marking line over the entire circumference with magic ink, etc. so that the cut point is at right angles to the pipe axis.

② The cut surface is smoothed with a file, etc., and the inner and outer circumferences are lightly chamfered at the same time.

- The concrete pipe should be cut with a cutter and should not be cut by beating with hammer.

- Existing pipes are to be cut in accordance with (1) to (9) of this section.

(c) Pipe protection work

- Protective work of pipe fittings such as shape pipedeformed tube shall follow the design document.

- If the construction supervisor (or supervisor) deems it necessary, appropriate protection should be provided in accordance with the instructions.

(d) Traversing major terrain facilities

- When crossing a road, river, or track, consult with the facility manager and establish a safe and secure plan for construction.

- Necessary measures should be taken to prevent flood control, vehicle traffic, etc. and prevent safety accidents from occurring.

(e) Pipe marking

- In accordance with the design drawing or the construction inspector (or supervisor)'s instructions, a pipe marking work indicating the location of the pipe burial should be installed.

2.7.5 Pipe connection

(a) Pipe connection with collar

- Centering on the already laid pipe, insert the collar up to half its length, and insert a wedge between the pipe and the collar to fix it.
- Align the center of the pipe to be joined with the center of the collar, insert it, and fix it by inserting a wedge between the pipe tube and the collar.
- Apply the mortar all over the joint, starting from the bottom of the joint. At this time, the lower part of the mortar should not fall.
- Backfilling should be done after concrete it has fully cured. In case of early backfilling, approval should be obtained from the construction inspector (or supervisor).
- The joint method using the color ring is not used for sewage pipes, including storm pipes, because it is difficult to fill the mortar and there is a risk of groundwater contamination and subsidence due to leakage.

(b) Socket junction

- Clean the rubber ring of the insertion hole and socket part, and insert the rubber ring into the end part of inserting pipe immediately before joining work at the installation site so that it does not twist.
- If it is necessary to fix the rubber ring in advance at the position specified in the design document, it should be attached at the factory. In addition, pipes with rubber rings should be constructed within a short period of time. If it is unavoidable to store the rubber ring for a long time after bonding it, it should be protected by wrapping black tape around the rubber ring to prevent the rubber from aging.
- When joining the pipe, lift the pipe to be joined using a chain block, lever block, etc., align the center line with the socket of the socket pipe installed at the base, and be careful not to twist the rubber ring and insert it up to the position specified in the design document.
- When using a lubricant, use an exclusive one, and do not use oil such as grease that deteriorates the material of the rubber ring.
- Fix the pipe by supporting it on the ground and loosen the chain block.

(c) Bonding by adhesive

- Before joining, the entire circumference of the outer surface of the end of the pipe should be chamfered about 2mm with a file or a knife, and the joint should be cleaned. If the pipe is cut, the end of the pipe should also be trimmed.

- Use a quick-drying adhesive for the adhesive, and apply it evenly and quickly with a brush to the outer surface of the TS socket and pipe insert.
- Adhesives mixed with harmful substances such as water and soil should not be used. Also, don't use the lower quality ones.
- After joining, the insertion state should be maintained for a certain time to prevent the pipe from slip out. Work inside the pipe should be done after excluding solvent vapor from adhesive.

(d) Flange joint

- Clean the flange and gasket grooves, completely remove harmful substances from the flange surface, and fix the packing between the flanges to match the inner diameter.
- Packings should be used with appropriate durability in terms of water quality, water pressure and temperature.
- Bolts should be tightened evenly throughout the circumference, not to one side.

(e) Mechanical joint

- The outer surface of the end of the end part of inserting pipe of the pipe is cleaned up to about 400 mm from the end.
- Check the direction of the gland ring, insert it into the end part of inserting pipe, and then apply lubricant to the rubber ring and insert it into the end part of inserting pipe.
- Lubricate the outer surface of the end part of inserting pipe and the inner surface of the socket, and insert the end part of inserting pipe into the socket.
- After sufficient lubricant is applied to the outer surface of the end part of inserting pipe, the inner surface of the socket, and the surface of the rubber ring, insert the socket into the end part of inserting pipe and make the distance between it and the pipe body 35mm.
- After straightening the gland ring so that the indicated diameter and year of manufacture are up, and inserting the bolt nut, alternately tighten the nuts diagonally so that the gland ring advances evenly all around the pipe tube body and tighten to the same torque.

(f) KP Mechanical joint

- Clean the outer surface and the inner surface of the socket for about 400 mm from the tip of the spigot.
- Clean the front and rear inner and outer surface bolt holes of the gland ring, insert both ends of the gland ring forward, and insert the gland ring into the tip of the spigot while turning it lightly.
- Put the rubber ring on the front surface of the tip of the spigot with oil that is harmless to the human body, and place it about 150mm from the tip of the spigot.
- Insert the pipe insert into the socket. At this time, in consideration of the expansion and contraction of the pipe, a gap of several millimeters is placed between the bottom of the socket and the end of the tip of the spigot.
- After making sure that the distance between the outer surface of the tip of the spigot and the inner surface of the socket is equal, insert the rubber ring carefully so as not to twist it in the predetermined position.

- If you fix the gland ring and hang the socket bolt directly from the upper side of the pipe to the socket jaw, it does not move left and right, so it is very easy to insert it while turning it slowly to the lower side.
- Care should be taken to fix the position of the pipe tube and to make the spacing equal by inserting a wedge between the gland ring and the outer surface of the spigot.
- Fasten the nuts with a spanner or a large trench diagonally, vertically and horizontally, and tighten the nuts in a balanced way over several turns.
- In KP mechanical joint, tighten the bolts in the order of the upper and lower nuts, then the nuts on both sides, and then the nuts in the diagonal direction so that the bolts are not tightened to one side only. Ensure that the spacing between the gland ring and the end of the socket is the same all around the pipe body. Repeat this operation and tighten with a torque wrench until the correct torque is obtained.
- The bolt tightening torque of KP mechanical joint shall be 60N·m in case of pipe diameter of 80mm and 90N·m in case of 100~600mm.

(g) Electrofusion Bonding

- In principle, welding is not performed in bad weather such as wind, rain, and snow. However, in the case of protective equipment, etc., construction may be conducted in consultation with the construction inspector (or supervisor).
- In welding work, be careful about electric shock accidents and burns caused by heat.
- Before welding, the attachments at the end of the pipe shall be completely removed.
- The end of the pipe is smoothed at right angles and then centered.
- Butt welding or socket welding is performed according to the design document.
- After welding, the joint should be sufficiently cooled before moving the pipe.(about 10 minutes in summer, about 5 minutes in winter).

(h) Welding joint

- During welding work, sufficient preventive measures against fire and short circuit should be taken, and ventilation should be paid attention to.
- During welding work, sufficient protective measures should be taken for the painting surface of pipe, and sufficient attention should be paid to the walking of the workers in the site.
- The parts to be welded should be sufficiently dried, and rust and other harmful substances should be completely removed with a wire brush, etc. and cleaned before welding.
- Welding is performed after completely removing and cleaning the slag and spatter of each layer.
- Welding in bent places should be performed after cutting the end of the pipe according to the angle and trimming the end to the specified dimensions. Also, when using a curved pipe in the middle, it follows this.
- In principle, welding should not be performed when there is wind, rain or snow. However, exceptions are made when protective equipment is installed.
- There should be no harmful defects such as cracks, lack of rust, blow holes, undercuts, slag mixing, uneven corrugation and corrugation, excessive or insufficient welding

thickness, and poor fusion.

- In principle, field welding is carried out gradually from one direction of the pipeline.
- In principle, the main welding is performed immediately after tack welding, and in the case where tack welding precedes, it should be stayed within 3 consecutive pipes.

2.7.6 Installation of auxiliary equipment

- Auxiliary equipment such as water drain valve, air valve, blow off valve, and flow meter should be installed accurately in accordance with the design drawings or construction specifications.
- The installation of the valve chamber, etc. should be such that there is no eccentricity in the settlement, inclination, and the opening/closing shaft.
- The control valve should be installed vertically or horizontally.
- After the control valve is installed, it should be adjusted with the connecting shaft so that the distance between the top of the adjustment shaft and the ground surface is secured about 30cm.
- When installing an air valve, a flange sluice valve with a handle should be installed directly on the flange of the T-pipe with a flange.
- The sediment valve should be installed near the concave part of the pipeline, where it is well connected to the river or drain, and the downstream part should be protected from scouring due to the effluent from the blow off valve outlet.
- Corrosion prevention measures should be taken when using iron or metal materials that are likely to corrode.

2.7.7 Construction inspection

(a) Bonding and internal inspection

- For welded steel pipe, conduct a radiation transmission test or ultrasonic flaw test according to the design document or construction specification, and follow the test methods as follows:

① General rule of ultrasonic testing of metals by the pulse echo technique: KS B 0817, JIS Z 2344, ASTM E 317, BS 3923, BS 7706

② Method of radiographic examination for welded Joints in steel: KS B 0845, ASTM E94/E94M-17, ISO 5579:2013, ASTM E1032-19, ISO 17636, ISO 10675

③ Standard qualification procedure for manual welding technique: KS B 0885, ISO 15614, EN ISO 15614-6 : 2006

④ Method of non-destructive testing for welded joint of pipeline: KS B 0888, BS EN 12517, ASME Section V - Nondestructive testing

⑤ Method of ultrasonic testing for welded joints of ferritic steel: KS B 0896, ASME Section V - Nondestructive testing, BS 3923, BS EN ISO 17640

⑥ Method of ultrasonic testing for detection in welded seam of arc welded steel pipes: KS D 0252, ASME Section V - Nondestructive testing, BS 3923, BS EN ISO 17640

- In the case of a steel pipe inner and outer fillet weld jointed pipe, the leakage by compressed air test is carried out at every joint.
- If the construction inspector (or supervisor) determines that it is necessary, take a test piece from an arbitrary location, check whether the welding is properly formed, and conduct a tensile strength test.
- The test results should be submitted to the construction inspector (or supervisor) for inspection.
- The welds that failed the inspection result should take a picture of the entire pipe circumference, remove the defective parts in detail, check the grooves, etc., and then re-weld and then re-inspect.

(b) Leakage test

- In the case of a concrete foundation, the test is carried out after sufficient strength has occurred after placing the concrete.
- The leakage test should be performed after filling the pipe with water and completely excluding air.
- Before filling or pressurizing water, refill should be done to the extent that it does not interfere with the piping work so that the pipe body does not move.
- For naturally flowing conduits with a diameter of less than 1,000 mm, the internal pressure head at the top of the conduit at the higher end shall be 1.0 m, and the test pressure should not exceed 5 m at the lower end. If necessary, the test may be conducted in two or three stages.
- For the test pressure, a head higher than the groundwater level formed at the top of the sewage pipe in the buried state should be applied.
- Depending on the supervisor's decision on whether or not to conduct the test, a leakage test may be conducted for pipes with a diameter of 1,000 mm or more. However, if the test requires a lot of water and is difficult to perform, it is substituted with a pneumatic or connection test, and visually inspected as an auxiliary test method. , CCTV investigation, smoke, dye and sound investigation can be conducted, and the results should be submitted after investigation.
- Leakage test procedure: One test section is inspected including the manhole between or in the middle of the manhole or the manhole alone. Before the inspection, the inside of the conduit is cleaned and the groundwater level is maintained lower than the reference water level (0.5m), do the following tests.

① At the lower end of the conduit, if necessary, also put a stopper that can withstand full water pressure to the branch pipe. A strut may be required to prevent movement of the pipe.

② A similar stopper or strut should be installed at the higher end to facilitate the erection of a hose or vertical pipe.

③ Fill with water to avoid air bubbles.

④ Fill the vertical test tube with water to the required level.

⑤ Leave it for the minimum preliminary time (30 minutes to 1.0 hours for concrete type, 10 minutes for non-concrete type) until the conduit is saturated.

⑥ After the preliminary time, fill water so that the head of the upstream vertical test pipe remains at least 1.0m, and then measure the amount of water required to maintain the initial head of the vertical test pipe at least 1.0m over 30 minutes. The vertical test pipe shall be watered every 5 minutes or when the head drop within 100mm occurs to maintain the initial head.

- Detailed application standards and allowable leakage are based on the following table.

Target[1]	Diameter of Application	App. head diff.[2] (Water pressure diff.)	Preparation time	Check Time	Allowable Head Reduction	Allowable Leakage[3] (L/m^2)
Conduit	less than 1,000mm	Minimum 1m(10kPa) on Conduit high side Conduit lower end Maximun 5m(50kPa)	donc Series:30minutes~10hours, Non-Conc Series:10minutes	0.5±1.0 hour	Δ1kPa or Δ100mm	0.15
Conduit + Manhole						0.20
Manhole	-					0.40
Joint	1,000mm	50kPa				0.15

Note) 1. Applicable to all pipe types

2. Applicable head can be calculated by water pressure, and corresponds to 100kPa =1 bar, 1 bar = 10m

3. Calculation of leakage: (Additional water) / (Area of tangent between water and pipe: π×diameter of pipe×length of pipe)

(c) Hydraulic pressure test

- Whether or not the hydraulic pressure test is performed and the details of the test shall be followed as prescribed in the construction specification.
- The hydraulic test shall be conducted after the leakage test is completed.
- The test is carried out after the air in the pipe is completely removed.
- The test shall be carried out after backfilling to some extent.
- The hydraulic pressure test is conducted by pressurizing the design water pressure (design water pressure + design water hammer pressure) to the irrigation canal with a hand pump, etc.
- The water pressure test can be omitted when the safety of the pipeline is predicted by testing the leakage test with the design water pressure and approval from the construction supervisor (or supervisor) is obtained. However, this does not apply to particularly important irrigation canals.

2.8 PIPELINE WORKS - HDPE Pipes

2.8.1 Pipeline Materials

(a) General requirements

All pipeline materials shall be suitable for waterworks purposes for the conveyance of water in the conditions prevailing in Malawi and in particular at the location of the Works.

All pipes shall be supplied in accordance with the relevant Standard specified or other Standard approved by the Employer or Engineer.

All pipes and fittings of any one kind shall be supplied to the same Standard except as otherwise allowed by the Engineer. The standard, method of manufacture, and specification shall not be changed at any time from that agreed between the Contractor and the Engineer except with the prior written approval of the Engineer.

Where material to dimensions shown on the drawings is not manufactured, the nearest available size above the size shown may be supplied, subject to the approval of the Engineer. The Contractor will be responsible for any redesign or extra design work and construction resulting from the use of material to other dimensions.

Drawings of all pipeline materials shall be submitted to the Engineer within thirty days of the award of the Contract and will be returned either approved or with comments within a further thirty days from receipt by the Engineer. Manufacture shall not commence until the Engineer has approved the drawings.

The Contractor shall identify the manufacturer of the pipe materials, the material types and classification. In addition, the Contractor shall provide evidence that the pipe material proposed is suitable for use at the design temperature and under the design pressure indicated.

Pipes and fittings shall be homogeneous throughout and free from visible cracks, holes, foreign inclusions, blisters, dents, scouring, cavities and other damaging defects. Joints are not acceptable.

Pipe materials shall be uniform in opacity, density, interior smoothness, and other physical properties. It shall have adequate resistance to weathering and other ageing from storage for a minimum of two years after manufacture. The pipes shall be manufactured from polyethylene containing only those anti-oxidants, UV stabilizers and pigments necessary for the manufacture of pipes conforming to the requirements of the Employer and specification.

(1) Color

The pipe shall be black with blue coloured strip marking.

(2) Carbon content

The carbon black content in the compound for black pipes shall be 2.25 + 0.25% by mass, when measured in accordance with ISO 6964.

(3) Dispersion of carbon black

When determined in accordance with ISO 18853 the dispersion of the carbon black shall be equal to or less than grade 3.

(4) Thermal stability

When determined in accordance with ISO 11357-6, the induction time shall be at least 20 min. when tested at 200°C.

(5) Effects on water quality

Materials in contact with water shall be certified from an internationally recognized authority such as WRAS Certification conforming its suitability to permanent contact with portable or irrigation water.

(6) Physical properties

Polyethylene pipes and fittings shall be high density polyethylene pipes (HDPE), and shall comply with the requirements of ISO 4427.

The material used for the manufacturer of pipes and fittings shall be in accordance with pipe dimensions shown on the table below.

The minimum required strength (MRS) of the material compound shall be 10 Mpa at 20℃ and 50 years life time. The design stress shall be 8 Mpa. The design temperature shall be above 40℃.

The HDPE pipes and fittings shall meet the following specification:

- Minimum density measured according to ISO 1872 > 959 kg/㎥
- Melt flow rate measured according to ISO 1133:
  - At 2.16 kg load < 0.15 g/10 min.
  - At 5.0 kg load < 0.5 g/10 min.
- Tensile strength at yield = 23 Mpa
- Elongation at break > 600%
- Thermal conductivity at : 0.4 W/mo k
- Vicat softening point at 1 kg load = 124℃
- The thermal stability of polyethylene material shall meet the requirement of ISO 4427.

(7) Dimensions of pipes

The pipe dimensions shall be based on standard dimensions according to ISO 4427 and measured in accordance with ISO 3126. The pipe dimensions, which are based on standard dimensions ratio 21 (SDR 21) are specified in the table below.

Pipe dimensions for SDR 21

Nominal outside diameter (mm)	Mean outside diameter (mm)		Wall thickness (mm)	
	Minimum	Maximum	Minimum	Maximum
200	200.0	201.2	9.6	10.7
250	250.0	251.5	11.9	13.2
280	280.0	281.7	13.4	14.9
315	315.0	316.9	15.0	16.6
355	355.0	357.2	16.9	18.7
400	400.0	402.4	19.1	21.2
450	450.0	452.7	21.5	23.8
500	500.0	503.0	23.9	26.4
560	560.0	563.4	26.7	29.5
630	630.0	633.8	30.0	33.1
710	710.0	716.4	33.9	37.4

800	800.0	807.2	38.1	41.2
900	900.0	908.1	42.9	47.3
1000	1000.0	1009.0	47.7	52.6
1200	1200.0	1201.8	57.2	63.1
1400	1400.0	1412.6	66.7	73.5
2000	2000.0	2018.0	85.8	95.4

(8) Pressure reduction factor for HDPE pipeline systems for use at temperatures above 20°C

Reduction factors to be applied to obtain the maximum allowable operating pressure for elevated – temperature operation of HDPE pipes and fittings shall comply Table 7 of ISO 4427.

(9) Fittings

The fittings shall be injection molded or formed from material compatible to that of the pipe. At locations where HDPE to metal/GRP connections are specified, stub flanges with PPV backing rings shall be used or special restrained transition fittings approved by the Employer or Engineer. The flanges shall be drilled to BS 4504, PN 16 as per the design requirements.

The dimensions of the fittings shall be measured in accordance with ISO 3126.

The wall thickness of the body of the fitting at any point shall be equal to or greater than the minimum wall thickness of the corresponding pipe.

(10) Hydrostatic strength

Hydrostatic strength of pipes and fittings shall comply to ISO 4427 when tested in accordance with ISO 1167.

(b) Inspection and testing

(1) Certification and documentation

The Manufacturer shall document and certify all products required tests and the Contractor shall supply the Employer or Engineer with copies of these certifications and test documents. Such documentation shall be subject to the Employer or Engineer's approval prior to shipping.

All items shall comply with the requirements of ISO 4427 and may additional requirements listed in this specification.

(2) Test and frequencies

The Manufacturer shall establish and maintain a current record of test results according to the requirements of the applicable standards and this specification. The Manufacturer shall perform all the tests required by ISO 4427 to demonstrated the characteristics and quality of the resin material and the dimensional tolerances of the pipe

The Manufacturer shall document all the tests, with frequencies and results as indicated in ISO 4427.

The Contractor or Manufacturer shall supply the Employer or Engineer, with copies of all material certificates and inspection and test results obtained in the course of quality verification.

When requested, the Manufacturer shall also provide access to and copies of all production record, process control charts, and other records compiled during manufacture.

(3) Inspection and audit requirements

Pipe shall comply fully with ISO 4427 and all the additional requirements of this specification. To verify compliance with this specification, the Employer or Engineer shall reserve the right to appoint an independent third party inspector to witness the applicable qualification tests, review production records, and inspect general handling and shipping procedures.

(4) Acceptance criteria

The order shall meet the following criteria:

- Copy of the raw material Manufacturer's "Certificate of Quality Control Testing" covering each batch of raw material used for pipes purchased under this specification, shall be available for inspection by the Employer's request.
- Pipe wall thickness shall be controlled by continuous scanning using gamma ray or other qualified devices. These devices shall be regularly calibrated for accuracy. Successful test performance and acceptable results for the testing program outlines in this specification. An acceptable inspection report from a third party inspection company (at the option of the Employer or Engineer).
- When performed, acceptable results from an independent test audit of any portion of the tests noted in ISO 4427 and this specification. The Employer or Engineer may reject any item that does not fully comply with the requirements of this specification.

(5) Defects

When the rejected item is a length or coil of pipe, the lengths or coils manufactured immediately before and after the defective lengths or coils shall be carefully examined. If further defects are found, this is sufficient cause for rejecting the entire batch. This will not apply to local damage that did not occur during manufacture, such as gouges and cuts during handling or transit.

(c) Quality assurance/Quality control

A copy of the Manufacturer's Quality Assurance (QA)/Quality Control (QA) plan shall be submitted to the Employer or Engineer with its quotation for review and concurrence prior to award. If Manufacturer's facility is ISO certified, QA audit requirements shall be waived in favor of ISO 9001 registrar audits, unless the Employer or Engineer's trend analysis program indicates areas of concern.

(d) Marking and packing

The marking information and sequence shall comply with ISO 4427 and this specification.

All pipes and fittings, including test samples, shall be clearly and permanently marked using indent printing in a colour that contrasts with the pipe.

All pipes shall be indelibly marked at maximum interval of 1 m and shall be displayed on the outside of the coil/length together with the following information:

- Manufacturer's name or trade mark
- Client "MINISTRY OF AGRICULTURE of MALAWI"

- Contract number
- Nominal outside diameter in millimeters
- Designation of the pipe material – Resin name or type
- The letters "PE" followed by the PE grade (e.g. PE100)
- The service, i.e. the word "Water" for water pipelines (blue marked)
- Nominal wall thickness
- Standard dimension ratio
- Coil/length number
- Plant location and date of manufacture
- Nominal pressure
- Production information
- 1 indicates extruder, and Y indicates compound supplier
- Number of the international standard

Fittings shall be marked as follows:

- Butt fusion fittings

  - Manufacturer's name and logo
  - Standard
  - Size in mm
  - Type of fittings
  - Standard dimension ratio (SDR)
  - Month and year of manufacture

- Electrofusion fittings

  - Manufacturer's name and logo
  - Standard
  - Size in mm
  - Type of fittings
  - Standard dimension ratio (SDR)
  - Weld time in seconds
  - Cool time in minutes
  - Month and year of manufacture

The maximum quantity of pipe to have the same coil/length number is one silo (coiled pipe) or one bundle (straight lengths). The maximum combined length of pipe in the silo or bundle with the same coil/length number shall not exceed the maximum allowable coil length.

When pipe material is boxed, the coil number shall be clearly marked on the outside edge of the box or silo. Invoices and packing lists shall include the date of manufacture and coil/length numbers for all material in the shipment.

The fittings shall be packaged in bulk or individually protected were necessary in order to prevent deterioration and contamination. The package shall have at least one label with manufacturer name, type and dimension of the fitting and number of units.

(e) Shipping

The Contractor/Supplier shall provide packing and shipping procedures for approval by the Employer or Engineer and shall comply with the following requirements.

(1) Delivery

Delivery of HDPE pipes and fittings to Work Site, shall be not later than six months after the stamped manufacturer date, for it to be acceptable.

Pipes boxed immediately after extrusion and stored indoors, as well as pipes protected from UV light immediately after manufacture as per the requirements of UV protection are exempt from this requirement and are acceptable up to one year after manufacture.

(2) UV protection

To obtain this exemption of UV protection, the manufacturer shall inform the Employer or Engineer one month prior to manufacture for inspection and approval of the protective method. All silos of coiled pipe shall be shrink-wrapped in UV-blocking black plastic. The black plastic shall be thick enough to prevent accidental tearing and passages of visible light. The UV-blocking plastic wrap shall filter out 100% of the UV radiation from reaching any portion of the pipe.

(3) Tie-downs

Tie-downs shall be at least 100 mm wide and be clean and free from sand, gravel and other materials. For straight length pipe a minimum 6 tie-downs are required.

(4) Pallets

The pallets shall be suitable for transporting the materials from the place of manufacture to the designated receiving location without causing any damage to the pipe. The pallets shall not contain any broken planks or extremities that may damage the coiled pipe or straight lengths. They shall be durable enough to prevent loose pallet nails from gouging the bottom of coil or straight length. Pallet construction shall be subject to approval by the Employer or Engineer.

(5) Overhang

Pipes shall not overhang at either end of the trailer.

(6) Stacking

The Manufacturer shall not ship small coils stacked inside silos of larger coils. Frames manufactured for the containment of straight lengths of HDPE pipe during transport and storage shall not contain nails or other fastening devices that may damage the pipe.

(7) Trucking

Where pipes are transported by vehicles, the vehicles should have a flat bed and free from sharp edges or projections. During transport, HDPE pipes shall be protected from diesel fumes and be continuously supported to prevent movement between the material and its support.

(8) End caps

HDPE pipes shall have internally fitted end caps that prevent direct and debris from entering the pipe during handling, storage and transport. Caps shall be attached by an approved method to prevent the accidental loss of cap. All end caps shall have an outer lip, which prevents the accidental insertion of the cap into the pipe. A method to permit venting shall be provided in order to allow expansion of air due to temperature changes during storage.

(9) Banding

All coils shall be banded at intermediate stages of coiling and upon completion of the specified length. At least 8 intermediate bands shall be provided on 150 m coils.

(10) Silo's

Silo packs of coiled pipes shall be squarely stacked and well supported on pallets. Coils shall not overhang the pallet and, unless approved by the Employer or Engineer, shall not be stacked higher than 2.3 m.

(11) Weathering

A certificate from the pipe and fitting manufacturers shall be provided, confirming that the products may be stored in the open for minimum 2 years without any adverse effect.

(12) Vendor documentation

The Contractor shall furnish, the following vendor data as a minimum, with the bid:

- Manufacturer pre-qualification documents
- Quality management system Certificate
- Type Test Certificate for Pipes, Fittings full "Third Party Type Tests Certificate".
- Catalogues or Brochures
- Dimensional details of pipes and fittings
- Detailed material specifications
- Manufacturer's drawings
- Complete details of testing facilities at manufacture works
- Local agent name and address
- Materials nontoxic to water Certificate "WRAS"
- Technical data sheet
- Compliance Statement to the Employer specifications
- Any other certificate required as per Standard
- Reference list showing experience details of supply & installation for minimum three years of performance history

(e) Acceptance of pipeline materials on site

Pipes and fittings will be finally accepted within the Work Site only when the following conditions have been observed:

- All damaged coatings and other repairs have been made good, in accordance with the manufacturer's instructions subject to the Engineer's approval.
- All pipes are stacked to the satisfaction of the Engineer, laid on suitable timbers on level ground and properly chocked.
- All fittings and boxes are laid out.
- The Engineer, or his delegated representative, has carried out a satisfactory inspection.

(f) Warranty

The manufacturer must give warranty for 5 years for all HDPE pipes and fittings from the date of the issue of the Provisional Taking-Over Certificate (PTOC).

2.8.2 Setting Out

The Contractor shall amend the drawings as necessary to incorporate the Engineer's comments and submit the number of copies which is made through discussion with the Employer and Engineer of the drawings detailing proposed horizontal and vertical alignments to the Engineer for approval. The number of copies which is made through discussion with the Employer and Engineer will be retained by the Engineer for his use.

Contractor shall be deemed to have inspected the work areas and their surroundings and to have satisfied himself as to the form and nature thereof, including sub-surface conditions, hydrological and climatic conditions, the extent and nature of the work, the materials necessary for the completion of the work and the means to access to all the work areas.

2.8.3 Pre-Construction Survey

Prior to any construction activities, the Contractor shall carry out a pre-construction survey to stake the pipeline centerline and define the Right-of-Way (ROW) by stakes placed at a distance of 100 meters maximum from each other and they shall not be disturbed and where the boundary of the ROW can be determined.

Contractor shall stake the entire pipeline routes as per the data available on the alignment drawings, in compliance with a Procedure Statement, to be submitted for Engineer's approval. The staking shall be based on the markers set along the pipeline route and construction drawings.

The contractor shall establish a reference point of 25 meters offset from pipeline centerline. The final pipeline alignment shall be subject to approval of the Engineer.

2.8.4 Right-of-Way (ROW)

The pipeline shall be located at the centre of the ROW, unless indicated otherwise. The Contractor shall coordinate with all local authorities and utility owners to obtain the approval of the ROW.

Prior to the commencement of any construction activities in the work area, the Contractor shall locate and identify all existing buried facilities, such as cables, pipelines, water mains, sewers, etc., including those not shown on the drawings, crossed or at close proximity with the pipeline, by contact with the relevant authority, carrying out appropriate surveys and exposing them by hand excavation, unless exempted in writing by the Engineer and shall be clearly marked.

The Contractor shall submit for approval a detailed proposal for precautions to be taken for avoiding or preventing damage to existing facilities above or below ground.

2.8.5 Clearing, Grading and Backfilling of ROW

During the preparation of the ROW, the Contractor shall grade the ROW to provide access to the pipeline during construction. The Contractor shall grade the ROW to remove sharp, high points, to minimize bending and to maximize laying with the limits permissible for elastic bending. Where the construction ROW passes through or along roads, tracks, pole lines, plantations or any other improved or confined areas, the Contractor shall grade only the width of the ROW necessary for digging the pipeline trench.

The Contractor shall establish Bench Marksand Intersection Points until the construction is completed. The Contractor shall carry out all survey and leveling of line and grades including as-built survey necessary to complete the work and shall be responsible for the accuracy of such survey and grades. The ROW for all the pipelines shall be staked by the Contractor so as to be able to define ROW boundary for purposes of clearing, grading and backfilling and shall be maintained throughout construction.

The Contractor shall install distinct markers locating and indicating special points, such as but not limited to contract limits, warning notices, presence of buried structures, obstacle crossings, change of wall thickness including corresponding chainage, etc. The Contractor shall grade and construct the ROW so that the trench is excavated in undisturbed ground. The Contractor shall grade sand dunes to allow vehicle access, safe laying of the pipeline within its elastic limit, and excavation of rock whether encountered. Fill materials shall be installed on the ROW as needed for vehicle access and make necessary arrangements such as ramps, temporary bridges, etc.

2.8.6 Crossings and Detours

It shall be the Contractor's responsibility to acquaint himself with all relevant requirements and regulations of authorities and Malawi government having jurisdiction over roads, pipelines, cables and other services on the ROW or crossing the ROW and to obtain their approval in writing and all necessary permits before commencing work.

The Contractor shall not close or divert roads without prior approval from the Employer or Engineer and the relevant authorities. The Contractor shall never unnecessarily hamper the users of the roads. At locations where any part of the work is routed along, over, under or across tracks or roads, the Contractor shall, with no extra compensation, provide and maintain detours, temporary bridges and road controls including warning lights as may be required by the concerned authorities.

2.8.7 Fences and Barriers

On completion of construction, the Contractor shall reinstate any damaged or relocated fencing on pipeline corridors and property boundaries to their original condition. The Contractor shall install suitable warning trench mesh on either side of ROW where it is essential to ensure safety and non-interference, especially in inhabited areas by suitable approved steel supports.

The Contractor shall provide and install heavy grade concrete barriers at any location where traffic might accidentally encroach on the construction. Fencing and barriers shall be continuously maintained.

2.8.8 Pipes Handling, Hauling, Stringing and Storage

(a) Receipt of pipeline material

The Contractor shall supply pipeline materials as specified in the Bill of Quantities at a designated area, subject to the Employer or Engineer's approval. Prior to taking delivery from the Supplier, the Contractor shall examine the pipes and satisfy himself about the condition of the pipes. After taking delivery of the pipes, the Contractor shall be responsible for their care and custody and for any repairs to any damage. Transportation of pipe to the Work Site is the Contractor's responsibility.

Any defective pipes shall be rectified or rejected as directed by the Employer or Engineer, then the Contractor shall supply new pipes as per applicable specification. The Contractor shall be fully responsible for arranging and paying for storage areas and method of storage shall be approved by the Employer or Engineer.

(b) Handling of pipe

The Contractor shall be responsible for handling, hauling, stockpiling, storage and stringing of the pipeline materials. Pipes shall be supplied fitted with end caps, which shall remain in place until the pipes, will be joined together.

The Contractor shall be responsible for providing suitable trucks and equipment in sufficient quantity to transport the pipeline in such a manner that prevents damage. Pipe, bends and other fittings shall be stocked, chocked and padded, and secured in position during transportation and during storage at pipe dumps or stringing in an approved manner. If pipes are supplied in bundles or on pallets, they shall remain so packaged until they are delivered to the location of installation on site. There are occasions where pipes may already be bundled in frames, in this case proper lifting equipment shall be used.

Pipes shall never be dropped onto hard or uneven surfaces. Pipes shall never be thrown from vehicles or be dragged or rolled along the ground. Rope or web slings shall be used with mechanical lifting equipment. Metal chains, hooks or cables shall never be used. Pipes generally be supported over their full length and not overhang by more than one metre. The Contractor shall lay out and measure the pipe so that the number of cut off pieces, less than 1.5 meters long, is held to a minimum.

(c) Hauling and stringing of pipe

Pipes shall be unloaded from the stringing trucks and lowered by hand, or by means of suitable approved equipment onto pipe supports, placed on the ground. Chains, cables or hooks inserted into the pipe ends shall not be used.

Pipes shall be strung alongside the trench on supports properly spaced with the pipe at least 100 mm clear of the ground. The trench is to be completely excavated, the area cleared of all debris, and the requisite bedding and base padding stockpiled, before stringing of the pipes.

However, the Contractor shall note and make allowance for sand drift into the trench in sandy areas, especially where sand dunes exist. The pipes shall be strung parallel to the ditch at a suitable and constant distance from the centre line of the ditch. The stringing of the ROW shall not put the pipe at risk and so as to cause the least interference with the normal use of access by trucks, etc. Gaps shall be left at intervals to permit the passage for traffic or equipment across the ROW or along public roads.

All pipe strung on the ROW shall be supported to be free from contact with the ground at all times. Pipe ends shall be protected with plastic end covers to prevent sand from entering the pipe while the pipes are strung along the ROW.

(d) Pipe storage

Pipes shall be stored in a secure and sheltered place and such material shall not be strung on the ROW but shall be transported along the line in covered conveyances for use when needed. Pipes shall be stored on a flat even surface capable of withstanding the weight of both pipes and lifting equipment.

Different sizes of HDPE pipes should be stored and transported separately. Where this is not possible, the larger diameter or thick wall pipe shall be loaded first having side supports at no more than 1.5 m intervals. All supports shall be free from sharp edges.

HDPE pipe materials shall be stored under cover, protected from direct sunlight and ensuring good ventilation. This will reduce exposure to UV light which over time can cause aging of the pipe surface. Any pipes stored at site shall be covered by tarpaulin. Storage in containers is not recommended.

2.8.9 Trenching

(a) Excavation and cover

The Contractor shall excavate the pipeline trench on the surveyed route as staked and to the design profile. The Contractor shall not start the ditching operations until the pipeline centerline has been approved by the Employer or the Engineer. The Contractor shall excavate the pipeline trench within the cleared and graded ROW using any method approved by the Employer or Engineer. Care shall be exercised to see that fresh material recovered from trenching operations, intended to be used for backfilling over the pipe in the trench or at the berms, is not mixed with loose debris or with foreign or rejected material, required to be removed from the site.

The trench shall be excavated to a minimum width so as to provide, on both sides of the installed pipeline, a clearance as specified in the typical drawings and to a depth sufficient to provide the minimum covers. The cover shall be measured from the top of the pipe, after it has been laid in the trench or placed on the formation level, to the level of the original ground or graded surface where such surface is lower than the original ground level.

<Minimum Cover Requirements for pipe>

Normal terrain and sand dunes	1.0 m (min.)
Track Crossings	2.0 m (min.)
City/Town/Inhabited Area	1.0 m (min.)
Metaled, Paved and Rig Road Crossings	2.0 m (min.)
Wade areas	3.0 m (min.)

The Contractor shall excavate to additional depth where the pipeline approaches and crosses other pipelines, sewers, drain pipes, water mains, telephone conduits, and other underground structures to facilitate the use of elastic bends.

The pipeline shall be laid with at least 1 meter free clearance under the obstacle or as specified on the drawings. If greater minimum distances are required by authorities having jurisdiction, those distances shall be maintained. Where the pipeline crosses areas whose easements specifically require greater than normal depths of cover, the trench shall be excavated to extra depth as required, including any necessary "lead in" and "lead out".

(b) Protection of other utilities

The Contractor shall provide all permanent protection and support for crossed utilities above and/or below ground. The Contractor shall be responsible for locating and protecting all underground lines and structures, whether shown on the drawings or not. The Contractor shall use pipeline locators and any other necessary means including manual excavation for locating all lines, utilities and substructures as part of his Scope of Work. The Contractor shall only excavate the trench within 1.5 m of such structures manually at no extra cost in compliance with the Employer or Engineer’s procedures. Any damage should occur to any structures/utilities, etc., the authorities concerned shall immediately be contacted by the Contractor and repairs shall be completed at the Contractor's expense.

(c) Grading and Padding

The trench or formation shall be cut or made to a grade that shall provide a firm, uniform and continuous support for the pipe, allowing for any necessary bedding and padding. Bends shall be made in the pipe at significant changes in grade of the trench.

The Contractor shall excavate at no extra cost the trench so that changes of grade will be by elastic bends, or bend the pipe to achieve changes of grade or when it is desired to reduce the required number of bends to a minimum to lay the pipe to conform to the general contour of the ground and maintain the minimum cover. This can be accomplished by cutting the trench slightly deeper at the crest of ridges and by gradually deepening the trench in approaches to road crossings and small water courses, if any.

The thickness of the compacted bedding shall not be less than 200 mm. In those areas that are to be bedded, the trench shall be at least 200 mm deeper than otherwise required, and evenly and sufficiently bedded to keep the pipe, when in place, at least 200 mm above bottom of excavated trench.

Acceptable bedding shall be placed under the pipeline before its installation, and padding around it after installation to establish at both sides and on top of the pipe a permanent layer of bedding. The thickness of compacted bedding around the pipe corrosion coating shall be at least 200 mm. Bedding and padding materials that are approved by shall be sand containing no gravel, rock or lumps of hard material or any other material that may be deleterious to the pipe coating.

On slopes, trench breakers shall be installed to prevent the migration of bedding and padding. Where the pipeline is to be laid in sand dunes, the trench shall be cut so that adequate trench bottom width is obtained in compliance with the applicable drawings.

(d) Trench crossings

The Contractor shall, in all cases where the trench has been cut across access roads etc., install a by-pass track or substantial temporary bridge work to the full width of the roads, of adequate strength, properly constructed to ensure the safety of the public and to allow passage of normal traffic with minimum inconvenience and interruption.

The Contractor shall arrange to complete the trenching, laying and backfilling of such crossings and to remove the temporary bridging before the end of the regular work day in order to minimize the hazard to night traffic.

The Contractor shall obtain the written permission of the appropriate authorities, before commencing work and shall ensure that all regulations and requirements of the authority having jurisdiction over such tracks are complied with. Proper warning signs shall be placed and maintained while such crossings are open.

(e) Protection of trench

The Contractor shall keep the trench in good condition until the pipe is laid and until backfilling takes place. No claim is to be made by the Contractor for the reason of the trenches collapse either before or after the pipe is laid. All materials necessary to shore the trenches in order to prevent collapse and for safety are to be furnished, installed and subsequently removed by

Contractor without any additional compensation.

In the circumstance of ground water being encountered, the Contractor shall provide adequately-sized dewatering equipment, shoring and any other equipment and materials required to excavate the trenches. All trenches and pits shall be excavated in dry conditions and kept dry during all phases of work until completion of backfilling.

2.8.10 Pipe Installation

(a) General

Prior to installation of piping, the trench preparation shall be checked for the required elevation, slope and freedom of rock, stones and other deleterious materials. The bottom of the trench shall be cushioned with well compacted soft bedding material to a minimum thickness of 150 mm below the barrel of the pipes. Any soft spots shall be excavated and refilled with lean mix concrete or selected fill materials as directed by the Engineer. Installation shall not be started until unsatisfactory conditions have been corrected.

Shortly before laying or fixing any pipe or fitting, the Contractor shall in the presence of the Engineer carefully examine it to ascertain damage or defect. All damage and all defects revealed by this examination shall be repaired and remedied to the satisfaction of the Engineer or replacement may be required.

The Contractor shall give the Engineer not less than 48 hours' notice of his intention to examine any pipes, etc. and the Contractor shall not proceed to lay such pipes until they have been approved as free from damage and defects by the Engineer.

The HDPE pipe itself may be partially or completely surrounded by concrete but should be protected by a heavy duty polyethylene membrane to a minimum thickness of 3 mm. If the pipe is laid in a sleeve, ensure that the sleeve ends are fitted in such way that no stress or cutting effect can be transmitted to the PE carrier pipe. The induction of stresses in the pipe or in joints during installation shall be avoided.

Installation of piping shall be in accordance with the Manufacturer’s recommendation and the Employer or Engineer’s requirements. All necessary precautions shall be taken to ensure a safe working environment in accordance with Malawi’s regulations.

When lifting pipe with slings, only wide fabric choker slings capable of safely carrying the load to lift, move, or lower pipe and fittings shall be used. Wire rope and chain shall not be used.

Joints between pipes and fittings shall be by butt fusion or electro fusion. Persons making heat fusion joints shall be trained and certified in the manufacturer’s recommended procedures.

Mechanical joints couplings and flanges shall be entered and aligned to the mating component before assembling and tightening bolts. Mechanical joints gland or flange bolts shall not be used to draw the connection into alignment. Bolt threads shall be lubricated and flat washers shall be used under the nuts. Tightening of bolts shall be even according to the tightening pattern and torque steps recommendations of the Manufacturer. At least 1 hour after initial assembly, flange connections shall be re-tightened following the tightening pattern and torque steps recommendations of the Manufacturer. The final tightening torque shall be as recommended by the Manufacturer.

(b) Required equipment

The following types and quantity of equipment shall be employed for activities associated with the HDPE pipe works. The equipment shall be operated only by Operators possessing necessary Site operation licenses.

Equipment	Quantity	Purpose
Electro fusion machine	As required	Electro fusion welding of fittings
Butt fusion machine	As required	Butt fusion welding of fittings
Hand peeling tools	As required	For HDPE pipe preparation
Clamps	As required	For clamping of HDPE pipes
Isopropyl cleaning tissues	As required	For cleaning of pipe surfaces prior to welding
Tent/cover for welding area	As required	For protection of weld area during welding

2.8.11 Pipe Jointing

The Contractor shall employ skilled personnel who shall be subjected to the Employer or Engineer's approval to perform all of the following jointing techniques to create HDPE pressure pipe systems.

- To joint lengths of straight pipe land incorporate fittings such as bends, equal tees and reducers; automatic butt fusion joining procedure shall be used.
- To join HDPE pipes to metal pipes and to valves; restrained transition fittings and stub flanges shall be used.
- To install off-takes or connections to existing lines, and on locations indicated and approved by the Employer or Engineer; electro fusion fittings may be used.

(a) Method Statement

A detailed method statement for HDPE pipe jointing shall be prepared by the Contractor, and submitted to the Employer or the Engineer for approval. This method statement shall include details of how the work will be performed to ensure compliance with all requirements and recommendations of the Manufacturer of Supplier of the HDPE pipe material and of this Specification.

This method statement shall ensure that all joints are of high integrity and shall include, but not by limitation:

- Procedures for the operation, maintenance, periodic inspection and testing of fusion tools and equipment.
- Procedures for joint preparation, indicating method and degree of cutting, cleaning, drying, scraping, alignment, support, etc. of the pipe ends to be joined.
- Jointing procedures, specifying the equipment and tools as well as all relevant parameters

(temperatures, pressures, heating time, cooling down time, joint fusion, etc.) and control of the jointing operations.

- Inspection and testing procedures and acceptance criterial together with proposals for independent inspection and testing on welds on a regular basis. As a minimum, 1% of all welds shall be tested on a regular basis and approved by a third party of testing body. The testing shall involve both testing of random welded joints and material characteristics performed by an independent test laboratory. All costs associated with the testing, together with any consequent rectification of faults and retesting shall be borne by the Contractor.
- QA/QC procedures
- All safety precautions and procedures

(b) Butt fusion welding

Butt fusion is a common technique for producing fusion welds in HDPE piping. The equipment employed shall be fully automatic and shall provide fusion data specific to each joint, which shall include each joint's unique number to form part of the as laid records.

All work shall be carried out under the supervision of a supervisor experienced in carrying out of installing HDPE pipe work. He/She should have sufficient experience in all aspects of the work including the fusion and back filling and pressure testing. The lead personnel involved in carrying out the fusion work will have been certified by the manufacturer of the welding machines used.

(1) Butt fusion inspection

All butt fusions shall be inspected and approved in accordance with the following criteria:

- The gap between the two single beads shall not be below the fusion surface.
- The displacement between the fused pipes must not exceed 10% of the pipe wall thickness.
- The difference between two single beads shall not exceed 10% of the double bead width.
- No signs of damage shall be visible on either side of the fusion.
- A bead gauge shall be used to assess the bead width. Bead widths shall be within the ranges specified in the below table and shall be of uniform appearance.
- The underside of the bead shall be examined and the bead inspected for lack of fusion, contamination, holes, offsets and melt damage.
- Bead shall be solid and rounded with a broad root. Hollow beads with thin root and curled appearance may have been formed with excessive pressure or no heat soak.
- A bead bend back test, shall be conducted where the bead is bent, around the finger, every few inches and the bead inspected for slit defects. This test will highlight fine contamination from the heating plate. Any joints found to be contaminated shall be cut out and a new joints made.
- Records of all tests and inspections shall be maintained by the Contractor and made available for review and approval by the Employer or Engineer.

Bead width

Minimum wall thickness, mm	Width of bead, mm

10	10 – 17
16	11 – 18
22	15 – 24
28	17 – 26
32	18 – 27
45	20 – 29
57	23 – 32

(2) Pre-joint checks

- Correct jointing parameters for the machine & pipe being welded shall be checked
- The generator shall be checked for sufficient fuel to complete the operation. Ensure that the generator is positioned away the welding area to avoid fumes. Generator used must be in accordance with butt fusion machine manufacturer's instructions.
- A voltage stabilizer must be used between the generator and the welding machine to protect machine from voltage peaks.
- Maximum cable length between fusion machine and generator is 50 meters.
- The calibration certificate for the generator, voltage stabilizer and welding machine should be valid.
- The welding equipment shall be checked for:
  - Correct plugs and sockets are being used.
  - The clamps must be effective in holding pipe square.
  - The trimmer blades must be clean and sharp and the trimmer must be square.
  - The heater plate must have a control system capable of maintaining a uniform temperature over the area in contact with the pipe.
  - The heat plate surface must be in a good clean condition with no damage to the PTFE coated surface.
- Pipe to be welded shall be supported on pipe rollers or HDPE pipe skids.
- Pipe to be welded is on good condition free from surface contamination and deep scratches (scratched < 10% of wall thickness are permissible).
- Equipment shall be cleaned to ensure that oil and grease do not contact pipe surfaces.
- To control dust contamination, welding shall be carried out in a protective shelter as per manufacturer's recommendations.
- To ensure that heat plate is fully clean, it shall be washed when cold with a mild detergent and then rinsed with cold water. A dummy weld will be completed every time the plate has been allowed to cool.

(3) Dummy welding

To ensure that contamination does not affect welds in installed pipes, a dummy weld shall be made at the start of any welding session after the plate has been allowed to cool. The welding cycle shall be followed up to the point where the pipe is removed from the heater plate. Following cooling of the pipe, the surfaces may be re-trimmed to allow production welding to begin. Alternatively, a scrap piece may be used and then discarded.

(4) Welding procedure

- Connect frame, hydraulic unit, heater plate, planning machine and data logger or CNC unit together using the cables provided.
- Ensure that hydraulic connections are clean, then connect to the hydraulic cables to the hydraulic unit and the machine frame.
- Connect the power supply cable to the voltage stabilizer.
- Start the generator then connect the voltage stabilizer to the generator.
- Select pipe material, size and wall thickness to be joined.
- Place pipes to be joined on rollers each side of machine.
- Follow instructions given by CNC control unit or data logger.
- Load planning device into the welding machine frame. Commence planning operation.
- When planning cycle is completed and carriage has opened, remove planner and swarf. Do not touch pipe ends. Do not pull swarf up through trimmed pipe ends.
- Perform visual misalignment check on pipe ends. (max. 10% of wall thickness misalignment allowed, max. 0.5 mm gap at pipe ends allowed).
- Close pipe ends to prevent draughts that can cause tunneling effect inside of pipe which can cool the heater plate.
- Clean faces of pipe ends and inside and outside with a soft clean cotton cloth using isopropyl alcohol (min. 70% alcohol).
- Secure heater plate on to welding machine frame.
- Close machine to press clamped pipes onto the heater plate to carry out initial melting and heat soak cycle.
- After heat soak cycle and upon prompting by machine remove heater plate and rapidly bring ends of pipe together to complete fusion weld.
- Allow pipe to cool using a timer to show the required time before removing from the welding machine clamps.
- Mark onto pipe near to joint with a silver indelible marker pen the following information for QA/Traceability purposes:
  - Date
  - Welders ID
  - Joint number
  - Machine number
  - Cooling time (i.e. time at weld completion + cooling time)
- Mark fusion joint number on as-built drawing for future cross reference of welding records.

- Check for cleanliness around the joint area

(c) Electro fusion welding

Electro fusion is a common technique for producing fusion welds in HDPE piping. Barcode labelled or auto recognition electrofusion jointing shall be used and only fittings incorporating fusion indicators shall be acceptable. Positioning tools including suitable mains alignment clamps shall be used for all types of electrofusion systems to minimize misalignment and prevent movement during the fusion and cooling cycle of the joint. A suitable shelter and mechanical scraper will be used for all jointing operations. All pipework to be washed prior to commencement to remove any contamination. After which, a uniform and efficient scrape shall then be performed to remove the oxidized surface to a depth between 0.2 and 0.4 mm. This shall be achieved using a mechanical scraper which is capable of cutting a continuous strip of swarf over more than the insertion length of the coupler and round the pipe. Only after preparation and scraping of the pipe end should the fitting shall be removed from its packaging and immediately inserted over the pipe end.

(1) Electrofusion inspection

A dot or line shall be initially marked on the pipe or spigot end to determine the depth of penetration. If a scraping tool is used which indicates the depth of penetration, then the marking requirement no longer applies. Each pipe or spigot end shall penetrate completely its relevant part of the electro-socket. Melt from the fusion process shall not exude outside the confines of the fitting. If this occurs the joint shall be removed immediately. If the fitting is designed with fusion indicators, after the fusion they shall be in a position complying with the fitting Manufacturer's instructions. Alignment clamps shall not be removed before the appropriate cooling time has elapsed. Abnormal displacement of the electric wire coils shall not occur. This shall be checked prior to commencement of fusion.

(2) Equipment specifications

All electro fusion equipment used will be suitable for use with electro fusion fittings having a bar code 2/5 interleaved to ANSO HM10.8M — 1938 and ISO CD 13950/0.8.94 rev.

(3) Applicable standards

Standards applicable to the use and operation of the electro fusion equipment include the guidelines from the DVGW Code of Practice, the DVS, and the appropriate national and local regulations.

(4) Joint identification and data retrieval

Each electro fusion operator will be furnished with a personal identification card. Each joint will be numbered and data entered and stored in the control box. The equipment will be capable of recording all pertinent digital joint fusion data for download to a PC based record system and as required, immediate printer read out.

(5) Cleanliness

Under no circumstances will heat fusion be carried out in conditions that are unsuitable for successful jointing. Trench side & trench conditions must be clean and dry and kept clear of ground water and mud. When necessary an enclosed habitat will be utilized to alleviate conditions of blowing sand.

(6) Supervision & skilled personnel

All work shall be carried out under the supervision of a supervisor experienced in carrying out installing HDPE pipe work. He shall have sufficient experience in all aspects of the work including the fusion and backfilling and pressure testing. The lead personnel involved in the carrying out the fusion work will have been certified by the manufacturer of the electro fusion machines or fittings being installed.

(7) Pre-Joint checks

- Correct jointing parameters for the machine & pipe being welded shall be checked.
- The generator shall be checked for sufficient fuel to complete the operation. Ensure that the generator is positioned away the welding area to avoid fumes. Generator used must be in accordance with butt fusion machine manufacturer's instructions.
- A voltage stabilizer must be used between the generator and the welding machine to protect machine from voltage peaks.
- Maximum cable length between fusion machine and generator is 50 metres.
- The calibration certificate of the generator, voltage stabilizer and welding machine shall be valid.
- The welding equipment shall be checked for:
  - Display screen working.
  - Bar code reader working.
- Connection plugs are clean, free from sand and make a secure fit on the fitting terminal.
- Correct plugs and sockets are being used.
- Pipe to be welded shall be supported on pipe rollers or HDPE skids.
- Pipe clamps are available and in good working order.
- Peeling tools are available and in good working order.
- Fittings to be welded are still in their original un-opened or damaged packaging.
- Pipe to be welded is on good condition free from surface contamination and deep scratches (scratched <10% of wall thickness are permissible).
- To control dust contamination, welding shall be carried out in a protective shelter as per manufacturer's recommendations.

(8) Welding Procedure

- Check surface of pipes to be welded to ensure that there are no stones embedded in the surface.
- Mark the insertion depths +10 mm on the surface of the pipe to be welded with an indelible marker.
- Remove the external oxidized layer of the HDPE pipe with an mechanical scraper up to the marked insertion depth +10 mm. Hand scrapers are not recommended.
- Remove all swarf from the pipe after peeling operation is completed.
- Where necessary ends of pipes shall may be re-sized and re-rounded with a mechanical

or hydraulic pipe re-rounder.

- Clean the peeled pipe surface and the inside of the pipe with a lint free cloth impregnated with Isopropyl Alcohol (min. 70%). Alternatively ready-made cleaning tissues containing Isopropyl Alcohol may be used.
- Remove fitting from bag (place magnetic card in pocket) and insert the ends of the pipe or spigot end of another fitting up to the pipe stop on the straight couplers or to the marked insertion depths on the pipe.
- Alignment clamps will be used to clamp the fittings secure for the fusion cycle in order to remove misalignment and stresses from the joint area during and after the fusion process. Clamps must remain in position until the entire fusion cycle including cooling has elapsed. On some fittings integrated clamps may be present in the form of fixation screws. In this case external alignment clamps are not required.
- Connect the power supply cable from the electro fusion machine to the voltage stabilizer.
- Start the generator then connect the voltage stabilizer to the generator.
- Once machine starts, enter welder ID card details via bar code on welder's ID badge.
- The electro fusion machine leads will be connected to the fitting to be welded, the bar code on the magnetic card or fitting should then be read into the electro fusion machine using the bar code scanner or 'pen' supplied with the electro fusion box.
- Press the weld button on welding machine and allow fusion cycle to fully complete.
- Allow pipe to cool using a timer to show the required time before removing from the welding machine clamps.
- Mark onto pipe near to fitting joint with a silver indelible marker pen the following information for QA/ Traceability purposes:-
  - Date
  - Welders ID
  - Joint Number
  - Machine Number
  - Cooling time (i.e. time at weld completion + cooling time)
- Mark Fusion joint number on as-built drawing for future cross reference of welding records.
- Check for cleanliness around the joint area.

2.8.12 Defective Members

Any HDPE pipe members which shall be found defective from any cause shall be cut out and replaced, and the cost of such cutting and replacing (including left over members) shall be borne by the Contractor.

2.8.13 Testing and Pre Commissioning

(a) Hydrostatic testing

Upon completion of the pipeline or a substantial part thereof, sections of the pipeline shall be cleaned and hydrostatically tested to prove integrity of the pipe section and to detect any leakage prior to commissioning. Leakage or faults usually occur at connections, joints, and mechanical seals where sealing under pressure is required.

Hydrostatic pressure leak tests of HDPE pressure piping systems shall be conducted in accordance with ASTM F 2164: Standard Practice for Field Leak Testing of Polyethylene (PE) and Cross-linked Polyethylene (PEX) Pressure Piping Systems Using Hydrostatic Pressure. The preferred hydrostatic testing liquid is clean water. The Contractor shall supply all necessary fittings, equipment, facilities, etc. including test ends.

(1) Method statement

The Contractor shall prepare detailed Method Statements for the pressure test, subject to the Employer or Engineer's approval. These Method Statements shall be based, but not limited to the requirements as set forward in the applicable codes and standard and in this specification.

(2) Test liquid and equipment

An adequate supply of a safe test liquid, such as water, is necessary. The test liquid shall be of appropriate safety and quality so that the environment, system, test equipment, and disposal are not adversely affected.

Liquid filling and pressurizing equipment such as pumps, and pressure regulating devices shall be necessary. Filling equipment shall be capable of filling the test section in a reasonable time against any elevation head pressure that may be present. Pressurizing equipment shall be able to maintain the necessary test pressure in the test section and provide sufficient quantities of make-up test liquid for the duration of the test.

For pressure monitoring, use at least one calibrated pressure gage or sensor accurate to within 2% of full scale. The gauge or sensor shall be located at the lowest point in the test section to monitor test pressure.

(3) Pre-test preparation and set-up

- Before testing, heat fusion joints are to be completely cooled.
- Flushing, pigging, or other means of cleaning the system to remove dirt and debris that may damage valves, regulators, and so forth, shall be required before testing.
- Restrain all parts of the test section against movement in the event of failure. Temporarily remove, restrain, or isolate expansion joints and expansion compensators before starting.
- Testing may be conducted on the entire system, or on section of the systems.
- HDPE pipeline materials are typically pressure rated at 23°C. At higher temperatures, reduced pressure ratings and test pressure shall be required. Contact pipe and fittings manufacturers for assistance with elevated temperature pressure ratings.
- The maximum test pressure is not to exceed 1.5 times the system design pressure where lower pressure-rated components or devices are not present, or have been removed or isolated from the test section. The maximum test pressure is not to exceed the pressure rating of the lowest pressure-rated component in the test section, where lower pressure-rated components cannot be removed or isolated from the test section.
- When the maximum test pressure is between system design pressure and 1.5 times the system design pressure or at 1.5 times the system design pressure, total testing time including the time required to pressurize, stabilize, hold test pressure, and depressurize

shall not exceed 8 hours.

(4) Test procedure

- (Filling) Fill the test section slowly. Purge all air. Take all appropriate precautions to ensure that no air is trapped in the test section.
- (Temperature equalization) Allow the test section and the test liquid to equalize to a common temperature.
- (Pressurizing – Initial expansion phase) When the test section is completely filled and purged of air, gradually increase pressure in the test section to the required test pressure. Add make-up water as necessary to maintain maximum test pressure for 4 hours.
- (Test phase) Reduce test pressure by 10 psi and monitor pressure for 1 hour. Do not increase pressure or add make-up water.
- (Pass/Fail criteria) If no visual leakage is observed, and pressure during the test phase remains steady (within 5% of the test phase pressure) for the 1 hour test period, a passing test is indicated.
- (Retesting) If retesting is necessary, depressurize the test section and correct any faults or leaks in the test section. Do not attempt to correct faults or fix leaks while the test section is under pressure.
- (Depressurization) Depressurize the test section by reducing pressure or releasing test liquid at a controlled rate.
- (After the test) Remove temporary closure and isolation devices from the test section.

(5) Test records

Information about the leak test shall be recorded and reported to the Employer or Engineer. Documentation shall include the following information.

- The test liquid and equipment
- The weather conditions and ambient temperature at the site during the test.
- The test pressure.
- The test duration
- A description of the test section length, elevations, and site location.
- A description of the test section components.
- Description of any leaks or failures and the corrective actions taken.
- The date and time of the day of the test.
- The identification of the party conducting the test.

(b) Disinfection and flushing of water pipelines

All pipelines shall be disinfected by the Contractor to the satisfaction of the Employer or Engineer.

The Contractor shall prepare a detailed Method Statements for disinfection. This Method Statements shall describe in detail how the Contractor proposes the various disinfection activities to ensure compliance with the requirements as set forward in this specification and applicable codes and standards, as well as with all requirements as set forward by the relevant authorities.

Before the pipeline is placed in service, and before issue of the Provisional Acceptance Certificates by the Employer or Engineer, all pipelines shall be disinfected and flushed as directed by the Employer or Engineer. The pipelines shall normally be disinfected at the same time as the hydrostatic tests performed or as directed by the Employer or Engineer. One week before the Contractor intends to undertake disinfecting and flushing of all or part of the pipelines, the Contractor shall submit a detailed proposal for the work showing the quantity of water required.

The chlorine dose shall be obtained from a chloral solution or other suitable solution to be approved by the Employer or Engineer. Samples taken from the pipeline during disinfection at locations directed by the Employer or Engineer shall be checked by a suitable comparator in order to ensure that chlorine is present throughout the system and at sufficient concentration. Samples shall be immediately submitted for chemical and bacteriological testing at the approved laboratories. All charges for water sample testing shall be paid by the Contractor.

At the end of the 24 hour period at operating pressure the chlorine concentration shall be checked. If there is less than 1 mg/L of free available chlorine in the water, more chloral solution shall be introduced and left for a further 24 hour period after which the free available chlorine concentration shall be checked again. This procedure shall be repeated as necessary until the free available chlorine taken after 24 hours exceeds 1 mg/L for all samples taken from the area of pipeline under test.

The hydrostatic test shall not be commenced until this requirement is satisfied. If the hydrostatic test fail and repair work involve emptying the pipeline, the disinfection and subsequent testing procedures shall be repeated in full. After all hydrostatic testing has been completed and section of pipeline is ready for handing over in all other respects including the installation of connections where appropriate, the new pipeline shall be flushed out by water from the existing mains to which the new pipeline is or will be connected.

Flushing entry and exit points shall be designed to allow a minimum of 1.0 m/s water velocity in the main pipeline to remove any sand or other debris. The quantity of flushing water shall be calculated as the equivalent to 3 times the volume of the pipeline to be flushed unless directed otherwise. The water at the point of extraction shall register a minimum of 0.4 mg/L of free available chlorine when tested with a site comparator prior to any approval being given to commence flushing. If obtained reading is less than this, then the Employer or Engineer shall be informed and the Contractor instructed accordingly.

(c) Connection to existing water pipelines

With respect to the connection of newly completed pipelines into the existing distribution or transmission system, and when successful pressure, chemical and bacteriological test results for the same are available, the Contractor may request for connection into the existing system in advance of preparing the new pipeline or network for handing over to the Employer or Engineer. At least two weeks shall be allowed for the application to be processed. The Contractor shall follow strictly the timings and periods of shutdown of the existing system as allowed by the Employer or Engineer.

The Contractor shall prepare all labour, plant and equipment well in advance of the proposed shutdown date and shall make advance preparations at the site of the connection so as to minimize the amount of work required during the limited period of shutdown allowed. No cutting of existing pipe work shall be allowed until a representative of the Employer or

Engineer's Operation and Maintenance section has given his authority for the work to commence after the necessary valves are closed also be present prior to works being allowed to commence. After the successful completion of the connection works and if agreed by the Employer or Engineer's operation and maintenance section shall again be called to re-pressurize the network.

If a valve is installed at the subject connection, it shall be maintained in a closed position and shall only be opened for specific flushing requirements at the instruction of the Employer or Engineer's representative. Commissioning shall only be considered for approval by the Employer or Engineer when the pipeline or network is completed in all respects and chemical and bacteriological tests have been successfully concluded. Handing over to the Employer shall only be considered with respect to the appropriate clauses for "Provisional Acceptance" of the works.

(d) Pipeline commissioning

The Contractor shall commission the pipelines after pressure testing, disinfection, flushing and after acceptance by the Employer and Engineer using approved procedures and plans. The Contractor shall prepare Method Statements with Work Procedure for the commissioning activities, subject to the Employer or Engineer's approval. This Method Statements shall be based on, but not limited to the requirements as set forward in the applicable codes and standard and in this specification. Once a procedure has been approved, any change in procedure shall be subject to written approval from the Employer or Engineer.

2.8.14 Quality Assurance/Quality Control

A copy of the Contractor's Quality Assurance (QA)/Quality Control (QC) program shall be submitted to the Employer or Engineer with its quotation for review. The Contractor shall identify in documents to its manufacturers, suppliers, vendors and subcontractors all applicable QA/QC requirements imposed by the Employer or Engineer, and shall ensure compliance. On request, the Contractor shall provide objective evidence of its QA/QC surveillance for all levels of its activity

(a) Documentation and records

The Contractor shall submit daily, weekly, monthly and after completion to various records and reports, for documentation purposes and immediately after the construction.

(b) As built drawings and pipe book

The Contractor shall prepare and submit "As Built" drawings 6 months after issuing PAC at the latest of all the Employer or Engineer issued drawings and of all Contractor work drawings including vender drawings. The documents shall be provided as hard copy and as soft copy. The drawings shall be prepared fulfilling the Employer's GIS system requirements and using the compatible AutoCAD version. Sample format of pipe book shall be submitted the Employer or Engineer's approval for all identified pipe elements.

<References for HDPE Pipeline Works>

1. Water directorate asset management department, 2014, "Standard Specifications for Water Works, Chapter 4: Engineering Specifications E- Pipelines works Specifications

2. The Plastic Pipe Institute, 2008, "Handbook of PE Pipe 2008".

3. ISO 4427 Polyethylene (PE) pipes for water supply specification or equivalent International Standard.

4. ISO-161-1 Thermoplastic pipes for the conveyance of fluids – Nominal outside diameters and nominal pressures – Part 1: Metric Series.

5. ISO-1167 Thermoplastic pipes for the conveyance of fluids – Resistance to internal pressure – Test Method.

6. ISO-3126 Plastic Pipes – Measurement of dimensions.

7. ISO-4065 Thermoplastic pipes – Universal wall thickness table.

8. ISO 6964 Polyolefin pipes and fittings – Determination of carbon black content by calcination and pyrolysis – Test method and basic specification.

9. ISO 9080 Thermoplastic pipes for the transport of fluids – Method of extrapolation of hydrostatic stress rupture data to determine the longterm hydrostatic strength of thermoplastic pipe materials.

10. ISO 11922-1 Thermoplastic pipes for the conveyance of fluids – Dimensions and tolerances Part: 1: Metric series.

11. ISO 12162 Thermoplastic materials for pipes and fittings for pressure applications – Classification and designation – overall service (design) coefficient.

12. ISO-13761 Plastic pipes and fittings – Pressure reduction factors for polyethylene pipeline systems for use at temperatures above 20ºC.

13. ISO- 7005-3 Metallic flanges – Part 3, copper alloy and composite flanges.

14. ISO 6259 Determination of tensile properties

15. ISO11357-6 Determination of Oxidation Indication Time (OIT) and Oxidation Indication temperature (dynamic OIT).

16. ISO 1133 Plastic – Determination of melt mas fear rate (MFR) and melt vacuum fear rate (MVR) of thermo plastic.

17. ISO 7005-3 Copper alloy and Composite Flanges – Part – 3

18. BS EN 12201 Plastic piping systems for water supply – polyethylene

19. BS 8010: Part 1 Pipelines on land.

20. BS 8010: Part 2 Pipelines on land design, construction and installation.

21. AWWA C651 Disinfecting water mains.

22. ASTM D3350 Standard Specification for Polyethylene Plastic Pipe and Fittings Materials.

23. F2164-02 Standard Practice for Field Leak Testing of Polyethylene Pressure Pipe Systems

Using Hydrostatic Pressure.

2.9 LAND SURVEY, GROUND INVESTIGATION, PHYSICAL PROSPECTING, AND SURVEY FOR CONDITION OF LOCATION

2.9.1 Land Survey

(a) General

Every land survey shall be in conformity with the working rules of public survey.
The Contractor shall be equipped with certified land survey equipment to ensure accurate survey in the field.

Surveyors shall be approved by the Supervisor, and the Contractor shall arrange the relevant personnel for smooth land survey performance.

The Contractor shall establish a land survey work schedule in advance of the survey, followed by approval of the construction supervisor.

The Contract shall perform the design confirmation survey among construction surveys to identify any discrepancy in the design documents within 30 days after the construction commencement, followed by submitting relevant documents to the construction supervisor.

The submittals include results of datum and auxiliary point surveys (a pocket register, a calculation book, and a performance chart); pocket books, drawings, and quantity calculation books (calculation of earth volume) of longitudinal and cross sections; and other products designated by the construction supervisor.

The Contractor shall carry out a construction survey for position measurements per process in this project before construction, followed by approval of the construction supervisor.

The submittals include a book of coordination system for the survey positions and a pocket register.

The Contractor shall carry out an inspection survey for the construction locations after the completion of each process in the project, followed by approval of the construction supervisor. The submittals include a book of coordination system for the construction locations and a pocket register.

The Contractor shall maintain the points of datum and surveying facilities for the construction until the construction completion as well as relevant survey products.

Every survey product relevant to this construction shall be signed and sealed by the head surveyor, including survey products for construction, inspection, and completion (pocket registers, calculation books, performance charts, and relevant documents), followed by submitting them to the construction supervisor.

Every accuracy or tolerance shall be determined by the construction supervisor according to the working rules in public survey and considering accuracy requirements for the construction.

The survey datum point shall be based on Topographic Bench Mark Point installed by Malawi governmental organizations.

The plane coordinate system shall be determined as Plane Rectangular Coordinates (TM system) or Global Coordinate System after consulting with the construction supervisor.

(b) Field Survey for Route

Field survey shall be carried out before the route survey along the scheduled route.

For effective survey performance, the field survey shall grasp conditions of survey obstructions, planimetric feature and shape, and traffic means first, and relevant data shall be collected and recorded.

An execution plan for detail surveying shall be established based on the data from the field survey. The work schedule for the survey may be modified if necessary.

The execution plan for detail surveying shall be submitted to the construction supervisor for approval. The submittals include the longitudinal and cross section drawings, relevant drawings and the details of plan such as the scale, the survey methods, and mobilized personnel and equipment.

(c) Selection of Points

Measurement points shall be determined appropriate to the topography of area considering efficiency, convenience, and accuracy of the construction survey as well as maintenance of the datum point and auxiliary points.

The measurement points shall be determined at locations with solid ground and observation convenience while not being interrupted by any natural disaster or traffic flow.

The interval between measuring points shall be distributed uniformly, and the calibration among the points shall be carried out adequately.

(d) Installation of Survey Datum Point

(1) Altitude Reference

The altitude references in the field shall be installed with an interval of about 500 m including the starting and ending points of the route.

The survey method for the altitude references is an amalgamation or combination. It shall start from a nearby Topographic Bench Mark Point installed by a Malawi governmental organization while being amalgamated or combined with another official Topographic Bench Mark Point. However, in case of an amalgamation of Topographic Bench Mark Point installed by a Malawi governmental organization, the bench mark shall be amalgamated with another one to ensure reliability.

(2) Horizontal Control Point

The Contractor shall install more than two horizontal control points at starting and ending point of the construction site (route). If the route is long, additional horizontal control points shall be installed with an interval of 500 m.

The horizontal control point shall be determined by GPS survey, triangular survey, trilateration, and traverse survey with a minimum of three national triangular stations.

In case of the traverse survey, the fixed traverse method shall be used, starting from one base line and joining with another one. The construction supervisor determines other matters according to the accuracy requirement of construction.

Public datum points have been installed for this project. They shall be confirmed by methods specified above Item before using.

The horizontal control points shall be installed at a convenient location, in that accessibility is relatively good on solid ground without any obstructions against using equipment such as GPS equipment.

(3) Datum point for semipermanent marker

The Contractor may install and operate datum points of semipermanent marker for the convenience of construction implementation.

However, the location and the survey performance chart for the datum points shall be approved by the construction supervisor before using them.

Datum point for semipermanent marker shall not be used for a prolonged time period more than three months. However, prolonged use of them may be granted when they are proven to be appropriate by re-inspection survey with an approval of the construction supervisor.

(4) Signs for the survey datum points

Altitude references and horizontal control points Altitude references and horizontal control points shall be installed at locations without modifications during construction on solid ground while calibration can be done appropriately. The size, shape, and material for the signs are determined after consulting with the construction supervisor.

Datum points for semipermanent markers The materials and sizes of the datum point stakes for semipermanent markers in the construction site shall be in conformity with the standards shown in Table (a).

(5) Maintenance of datum points or etc.

The Contractor shall specify the installed datum points (for horizontal control and altitude reference) on the drawings, and the survey results shall be reported to the construction supervisor. However, the datum points (for horizontal control and altitude reference) may be installed outside the construction site if necessary with an approval of the construction supervisor.

The Contractor shall maintain the datum points from the initial construction to the completion.

Table (a). Materials and sizes of the datum points for semipermanent markers

Classification	Material	Color	Size (cm)
BC and EC stakes	Wood or plastic	Blue	4.5×4.5×45
IP stake	Wood or plastic	Blue	6×6×60
Center stake	Wood or plastic	Red	4.5×4.5×45
Semi-permanent marker stake	Wood or plastic	White	9×9×75
Stake for longitudinal	Wood or plastic	Red	4.5×4.5×45

change point			

Horizontal control points and altitude references installed at site shall be marked by an easily distinguishable way, followed by installing protection. A report containing pictures of surroundings shall be prepared and submitted to the construction supervisor for approval.

The report of point shall specify the survey product in details including the time of installation (installer), time of survey (surveyor), address of the point, and overview and specification of the point.

When reinstallation of a datum point is required due to partial loss or damage of the point or ground displacement or an obstruction, the Contractor shall immediately stop using the datum point and report the condition to the construction supervisor for approval of the reinstallation.

The maintenance of reinstalled datum point shall be carried out in an identical way with the existing ones.

(e) General Detail Survey

Following matters shall be checked for detail surveying.

(1) Survey methods, personnel, and equipment shall be secured to satisfy the required accuracy.

(2) Personnel arrangement chart for the surveying shall be prepared.

(3) Survey instrument and equipment shall be inspected and calibrated.

(4) Necessary material for the survey shall be purchased.

(5) Permits and licenses shall be acquired to access the survey sites.

(6) Consultation between relevant authority and the owners shall be done in advance of woods logging and survey obstruction removal.

Expression of calculation during surveying such as coordinates shall be in conformity with the standards specified in Table following.

The tolerance in observation and calculation shall be determined by the construction supervisor according to the working rules of public survey and considering the accuracy requirement of construction.

Classification	**Direction Angle**	**Distance**	**Altitude**	**Coordinate Values**	**Area**	**Volume**
Unit	Sec.	m	m	m	m^2	m^3
Decimal points	1	0.001	0.001	0.001	0.01	0.01

(f) Installation of a Point of Intersection (IP Point)

The existing detail surveying products shall be used. More, IP points are surveyed and installed by GPS or Total Station (T.S.) equipment, Deodolite, and Electronic Distance

Measurement using the installed datum points (for horizontal control and altitude reference) in site.

IP points shall be directly surveyed and installed in site considering surrounding conditions, and the materials and size for the stake shall be in conformity.

However, a referring point may be installed and used at locations that IP point installation is obstructed.

(g) Surveying Center-line

Center-line survey shall be carried out in the site according to the existing detail design document, and a numbered stake shall be installed rigidly in the site. However, a hardware or paint shall be used to indicate the center-line at locations that stake installation is impossible due to a structure or pavement with an advance approval of the construction supervisor.
The interval between measurement shall be 20 m, and plus stakes shall be installed at critical points for the construction such as longitudinal or cross-sectional changing points, a structure installation point, and starting and ending point for a curve (starting and ending point for an easement curve). However, the interval of measurements for a river center-line surveying may be adjusted after consulting with the construction supervisor.
The standards for stakes to be installed at each measurement point shall be according to Table.
Distance measurement shall be accurately done using Electric Distance Measurement (light or electromagnetic wave), T.S. equipment, or GPS. However, a steel tape may be used for measuring a short distance less than 50 m.

(h) Installation Surveying for Temporary Bench Mark

Temporary bench marks (TBM) may be installed at the field, and the altitude of TBM is determined for use by surveying it from an existing altitude reference. However, when a distance mark is available for a river or etc., it may be used as TBM with approval of the construction supervisor. The distance mark shall be surveyed from the altitude reference for confirmation.

A rigid structure may be used to indicate TBM, or a temporary stake for TBM may be installed.

A report of point shall be prepared when TBM is installed, and it shall be kept in the field.

(i) Longitudinal Leveling

Longitudinal leveling determines the altitude of center-line based on the installed measurement point on the center-line as well as center, plus, and referring stakes installed at critical points

Longitudinal leveling is carried out as a direct leveling considering topography and surrounding conditions. In case of an unavoidable case, indirect leveling may be carried out with approval of the construction supervisor.

When the observation point starts from a TBM, the reliability of performance shall be ensured by joining it with another TBM or an altitude reference.

The longitudinal change point and locations of critical structures should be determined by measuring distances from the center point.

The stake for longitudinal change point shall be installed at the longitudinal change point.

In case that stake installation is impossible, it may be indicated by paint or a hardware product.

(j) Cross Leveling

The left and right ranges of cross leveling shall exceed the lot boundary, and they need to be approved by the construction supervisor.

Cross leveling measures heights at altitude changing points or distanced from the center stake that perpendicular to the center-line in the right and left directions at the location of center stake installation.

The ground altitude is measured during a cross leveling by a direct leveling or an indirect leveling depending on the topographic conditions. However, the cross leveling is conducted across a river or on the coast, an appropriate method shall be employed. In those cases, surveying methods other than the direct leveling shall acquire an approval from the construction supervisor.

The scale, drawing standards, and preparation method shall be approved by the construction supervisor when drawings for the longitudinal and cross leveling are prepared based on the surveying.

(k) Surveying Cross Structure

A cross leveling shall be carried out to check whether a cross structure is in line with a water channel or a road direction in its design of inflow and outflow gates or not.

The range of this cross leveling shall exceed the public work's boundaries over 50 m, and it can be extended depending on the topographic conditions. Especially for drainage plans, drainage potential to the terminal draining point shall be confirmed.

A detailed construction drawing shall be prepared in a way that an access road or a water channel confluence is in line with the local topography, considering the results of cross leveling and surrounding topographic conditions.

Other scopes of inspection for critical structures are to be determined by the construction supervisor.

2.9.2 Ground Investigation

(a) General Scope

This specification is intended for applying to ground investigation to acquire necessary ground information for design and construction of the project. BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

(b) General Affairs of Investigation and Test

The ground investigation during construction shall be carried out in a way that provides overall required data for design confirmation or changes. When a deformation or damage occurs to the structure or when the safety of structure is assumed to be jeopardized due to changes in the surrounding conditions, the ground investigation shall be carried out to find the cause and to prepare measures against the situation.

Tests shall be carried out by qualified engineers for the quality test/inspection or equivalent personnel having the identical experience and capacity, followed by confirmation with the construction supervisor.

When any personnel for the investigation or test need to be changed, it shall be approved by the construction supervisor.

Soil test shall be carried out immediately after sample collection.

If any significant changes in the sample transported into the laboratory is identified or if a test fails or if the sample is insufficient, the situation shall be immediately reported to the construction supervisor before recollecting the sample.

When a collected sample is assumed inappropriate for a certain test, the test shall be stopped by the direction of construction supervisor, or retest shall be carried out after recollecting the sample.

When a test required a prolonged period of time, a supplementary device shall be employed to ensure the accuracy of test results.

A inspection location shall be determined after acquiring approval of the construction supervisor, and its location, depth, and altitude shall be measured accurately. However, geodesy engineers or equivalent personnel shall carry out an investigation with precise survey requirement, followed by confirmation with the construction supervisor.

Type, number, and location of test including in-site tests shall be determined in collaboration with the construction supervisor. Purpose and progress of the test may be modified depending on the local condition after acquiring approval of the construction supervisor

Test agent may conduct a test by acquiring approval of the construction supervisor to promote safety and effective test implementation. As a phase in the test is completed, it should be reported to the construction supervisor stepwise.

Every test shall be conducted in the presence of the construction supervisor. However, if it is not possible, a report for the procedures shall be made and submitted to the construction supervisor before the test, and the purpose of test shall be fulfilled.

Test results shall be prepared in documents, and a relevant report shall be prepared and submitted to the construction supervisor. The report needs to be prepared in A4 size, and pictures showing test procedure shall be attached to it.

The Contractor shall prepare measures to minimize public nuisance when conducting a site quality management test

(c) Surface Geological Survey

Surface geological survey is intended for supplementing existing investigation by grasping overall topography, geological features, rock quality, soil, and ground water.

A geological feature structural map is prepared for faults, flexures, and joints while potential of geological disaster shall be assessed by investigating rock distributions and properties.

During the surface geological survey, following matters shall be indicated on an engineering geologic map, and it shall be submitted to the construction supervisor.

(1) Surface ground: Surface soil, weathering soil, types of sediments (river sediment, alluvial fan deposit, terrace sediment, collapse deposit, and ejecta of volcano) and their distribution, constitutions, thickness, crystalline degree, moist contents, permeability, and mobility

(2) Rock condition: Types of rock, grain size, arrangement of rock forming minerals, pore condition, metamorphic and aeration grades, stratification bedding, foliation, and etc.

(3) Geological structure: Geological distribution, stratification of strata, strike and slope, fault, flexure, joint, crushing zone, alteration zone, and etc.

(4) Underground cavity: Natural cavity (limestone cavern), mine, closed mine, mine in the

past, and etc.

(5) Behavior of bedrock: Existence of expansible or movable bedrock and its distribution, existence of potential bedrock collapse due to spring water, and potential of uneven pressure

(6) Surface and ground water: Flow condition of surface water, condition of ground water, water temperature, water quality, constitution of aquifer, level of ground water, relationship between aquifer and geographic feature, and condition of spring water

(d) Soil Test

(1) Preparation of sample

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) Samples for a dynamic test shall be prepared especially carefully not to allow being scattered or moisture evaporating.

c) A test specimen shall have a minimum weight at least for single test.

d) If a sample introduced in the laboratory is considered being scattered or altered such as moisture evaporation, the sample shall be recollected for the test.

(2) Mechanical analysis of soil

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) The temperature/pressure chamber shall not cause any vibration to the water tank. The Contractor shall prepare measures to minimize public nuisance when conducting a site quality management test

(3) Tests for the liquid and plastic limits of soil and coefficient of contraction

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) With an approval of the construction supervisor, a test may be conducted with a natural moist content or a dry condition similar to it. The test conditions shall be recorded in the test log.

(4) Test for Soil Moist Content

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) The representative sample shall be prepared from the core that has not been dried at all.

c) The natural moist content of the transported sample in the laboratory shall be carried out first, and the identical scale shall be used for the soil moist content.

d) The Contractor shall confirm the safety of equipment before the rapid moisture measurement using radiation, and the inspection to the equipment shall be done in the presence of the construction supervisor.

e) The Contractor shall prevent any equipment move or radiation leakage during test.

(5) Test for specific gravity of soil

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) The weight of the specific-gravity instrument shall be measured together with the stopper at all time. The specific gravity is determined as the average of two or more tests while test shall be redone if the deviation of two specific gravities is more than 0.03.

(6) Engineering classification methods of soil

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) The constitution system of soil, which includes the grain property, liquid and plastic limit, and mineral and organic mineral components by laboratory measurements, shall be expressed according to a general classification method

(7) Test for soil compaction

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) In case of test for viscous soil, the dryness of test sample should be checked by the construction supervisor. The moist contents before the test shall be recorded in the test log.

c) The guides of rammer shall be located on the sample surface at all the time while preventing any friction in between the guide and rammer.

d) After compaction, test shall be redone if the thickness of first layer is significantly different to the rule.

e) A minimum of 6 measurements are required for the moist content curve.

f) A new sample shall be used for every test (non-repetitive method) if moisture increase is not applicable for the sample such as clay or if the sample is fragile.
Relevant results should be recorded.

g) When a test is carried out while reducing the moisture content of sample, it should be approved by the construction supervisor.

(8) Soil CBR test

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) A screw jack shall be used as the loading equipment in the test.

(9) Unconfined compression test

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) Strain-controlled type device shall be used for the test.

c) Loading shall be continued until the deformation rate reaches 15 % or above though no clear sign for demolition is identified.

d) Reshaped sample by kneading shall be wrapped by a sheet of vinyl to prevent any change in moisture content, and knead it manually again on the desk while rotating it bit by bit. The manual kneading shall be done more than 300 times.

(10) Tri-axial soil compression test

a) BS or other equivalent test standards may be employed after consulting with the

Employer and the Supervisor.

b) Loading shall be continued until the axial deformation rate reaches 15 % or above though no clear sign for demolition is identified.

(11) Soil consolidation test

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) The consolidation test determines the deformation degree and time while load is applied to it allowing drainage on the axial direction and blocking one side of soil

c) Rowe cell consolidation and permeability test

1) When a major deformation of soft ground is anticipated and when a ground improvement is carried out by horizontal drainage, it shall be conducted parallel with conventional oedometer test in order to determine consolidation properties.

2) The diameters of sample can be 75 mm, 150 mm, or 250 mm. Appropriate diameter shall be determined considering the soft ground improvement and ground purpose for the test.

3) When ch (Rowe cell consolidation and permeability coefficient) is calculated by the test, test shall be done for surrounding Rowe cell consolidation and permeability using free strain. The pore water pressure at the central portion should be recorded.

(12) Soil permeability test

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) In case of a static water level permeability test, the sample tube may be used as is for non-dispersible sample. When the test is done transferring it to the permeability cylinder, the gap should be filled with patching bentonite.

c) When the test is done for non-dispersible sample, the relationship between natural and test directions of permeability shall be recorded.

(13) Direct Soil Shearing Test

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) Pay special attention not to agitate the natural sample.

c. The friction of shearing box shall be minimized.

(14) Soil plaste bearing test

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) Soil plaste bearing test is employed to determine bearing capacity factor for appropriate load on roads, roadbed, and footing foundation.

(15) Soil Unit Weight Test in the Field

a) BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) If the maximum grain size of the object ground for the site unit weight test exceeds the allowable range, Sheet method or other methods approved by the construction supervisor may be employed for the test.

c) Pay special attention to manage test sand, and the sand shall not be used for more than three times if it is standard sand.

d) When the soil as original material shows significant alteration or when the unit weight as standard is changed, the laboratory compaction test shall be repeated to determine the standard dry weight.

(e) Test of Rock

(1) Shaping and preparing test piece and general test

a) Methods to shape and prepare a test piece shall be in conformity with specifications in BS, Suggested method of ISRM: International Society for Rock Mechanics and American Standards for Testing and Materials (ASTM).

b) Three or more test pieces should be prepared for each rock samples that 2 to 3 are taken from each drilling hole for the test.

c) The rock samples should be taken out of the representative ground portion considering its weathering, cracks, orientation, and moisture contents. When they are collected from an unusual portion, it should be clearly indicated.

d) The Contractor should pay attention following factors that may influence the Soil permeability test

1) Shape and size of test piece

2) Finish of the upper and lower bearing sides of the test piece

3) Contact between the pressing face of the compressing equipment and the bearing sides of the test piece

4) Dryness

5) Loading methods such as loading speed and deformation speed

(2) Confined rock compression test

a) Confined rock compression test shall be in conformity with ASTM D 2938 and 3148

b) The test piece should be prepared in a corn shape with a ratio of diameter to height more than 2.0.

c) The diameter of test piece should be larger than NX size.

(3) Rock tensile strength test

a) Rock tensile strength test shall be in conformity with ASTM D 2936 and 3967.

b) The test piece should be a corn shape with a ratio of diameter to height 0.5 to 1.0, and the diameter needs to be larger than NX size.

c) Test may be conducted according to methods suggested by International Rock Dynamics Society. It can be either direct or indirect tensile strength test.

(4) Tri-axial rock compression test

a) Tri-axial rock compression test shall be in conformity with ASTM D 2664.

b) The test piece should be prepared in a corn shape with a ratio of diameter to height more than 2.0.

c) The diameter should be larger than NX size or more than ten times of the maximum rock grain.

(5) Rock elastic save velocity measurement test

a) Rock elastic save velocity measurement test shall be in conformity with ASTM D 2845.

b) The test piece should be larger than NX size, and the length needs to be longer than 5.0 cm.

c) The test piece should have parallel edges that are perpendicular to the measuring axis.

(f) Test Excavation

When a direct inspection is needed for a special ground condition or when specific in-site test is required, the ground may be investigated by a test excavation.

(1) Test excavation plan

a) In advance of a test excavation, a plan should be prepared including following aspects and submitted to the construction supervisor.

1) Location and time of the test excavation

2) Purpose of the test excavation (type and number of a soil or a rock test)

3) Dimension of the test excavation

4) Method of the test excavation (excavation equipment and depth)

5) Safety measures for the excavation

(2) Test excavation

a) A test excavation should be executed in the presence of the construction supervisor.

b) The test excavation should be photographed.

c) The test excavation should be executed at a flat location with good drainage and bearing power.

d) Any potential collapse due to rain should be prevented by applying a waterproof sheet or vinyl sheet during the test excavation.

e) As soon as the purpose of excavation is fulfilled after the test excavation, the site should be refilled with a compaction that exceeds the original level. However, it may be exempted if a follow-up construction is scheduled with an approval of the construction supervisor.

(3) Reporting the test excavation results

a) A report should be prepared to summarize the results after a test excavation, and it should be submitted to the construction supervisor.

b) The report should include the following items.

1) Discrepancy with the design documents and the object ground of the test excavation

2) Ground properties including soil, rock, and ground water level

3) Drawings and pictures showing details of each cross sectional investigation of the test excavation

4) Types and results of each soil or rock test performed after the test excavation

5) Other required items

(g) Drilling

In advance of drilling, the constitution of ground bed, location, and width of a surface of discontinuity, such as fault and crushing zone, and outflow discharge of ground water should be grasped. More, a drilling investigation should be preceded if a field test is required by collecting samples from drilling. A slop drilling may be allowed considering the purpose of investigation and the field conditions.

(1) Types of drilling

The drilling machine type should be of Rotary Drilling with Mud Water Flushing. However, depending on the ground property and the relevant construction method, one of Auger boring, rotary boring, wash boring, or percussion boring machine may be used with an approval of the construction supervisor.

(2) Size, interval, and depth of borehole

a) The size of borehole for a ground investigation should be larger than NX, and the casing should be installed down to the weathered rock to maintain a borehole wall.

b) In case that sample is collected by a thin walled tube from the borehole, the borehole should be 10 mm larger than the outer diameter of the tube. Otherwise, it should be approved by the construction supervisor.

c) When a cross bearing test, a field permeability test, or a pore water pressure measurement is to be carried out in the borehole, the size of borehole should be larger than NX.

d) The interval and depth of borehole should be determined according to the soil survey report. However, an inspection boring around a structure in a limestone region should be carried out after consulting with the construction supervisor since numerous cavities are scattered throughout the region.

(3) Management of boring

a) The Contractor should appoint boring engineers before the boring works, and it should be approved by the construction supervisor. The boring works should be carried out in the presence of the engineers.

b) In advance of boring, leveling should be done from a datum point designated by the construction supervisor, and the relevant boring altitude should be determined and indicated on the ground plan.

c) During boring works, pay attention to the propelling speed, load pressuremeter, pump pressuremeter, volume of water and outflow discharge, and color of drainage, slime condition, and mixture with foreign substances. Any change of them should be recorded along with the relevant depth. Do not ignore a thin stratum.

d) When spring water is identified during boring, measure and record the relevant depth accurately. Moreover, the water level in the borehole should be recorded before starting work daily until the completion of investigation. The normal water level should be determined in consideration of the water level in nearby wells and seasonal water level fluctuation.

e) Cementation should be approved by the construction supervisor.

f) When boring is intended for collection rock or equivalent core samples, works should be carried out paying attention to the following items.

1) Boring should employ a double core barrel with a diameter larger than NX.

Triple core barrel or D-3 Sampler needs to be used in a weathering or crushing zone in order to enhance the core return rate and to collect sample in the original condition.

2) Unless it is unavoidable to prevent an accident during boring, the core should not be damaged by elevating or descending the loader or by repetitive sudden pressure changes.

g) Shape, rigidity, color, grain size, moisture condition, and mixed substances should be recorded after collecting the sample.

h) If the purpose of investigation is fulfilled before reaching the estimated boring depth or if the purpose of investigation is not fulfilled though the estimated boring depth has been reached, it should be immediately reported to the construction supervisor for a follow-up direction.

i) After completion of the boring investigation, arrange surroundings, and close the borehole. When a long-term observation for the ground water level is needed, a protective cap should be applied after consulting with the construction supervisor.

j) For working in a region with anticipated obstruction such as underground facilities, an advance consultation with the relevant authority should be done for the relevant installation depth and location. It should be started after getting approved.

(4) Summary of the results

a) Detailed information from each borehole should be recorded the soil column map of the borehole. The boring engineer and investigator should add following information on the soil column map in the field.

1) Name of the boring investigation and the number of borehole

2) Location and investigation period, names of boring engineers and investigators

3) Coordinates and ground altitude of the borehole (surface altitude)

4) Quantity (depth) and type of borehole

5) Boring machine and its diameter

6) Date of ground water level evaluation and observation

7) Ground stratification

8) Results and depths of the standard penetration test

9) Depth, shape, and length of the collected soil sample

10) Drawings and pictures showing detailed investigation for each cross section of the test ground excavation

11) When a rock test piece is collected, the core collection rate, RQD, name of rock, color, interval and slope of joint, and the roughness of the joint face should be recorded.

b) The engineers should prepare a new soil column map after completing necessary laboratory tests including the field and laboratory test results and relevant annotations.

c) The Contractor should submit the soil column map (final report) with the engineer's sign in a number of copies required by the construction supervisor.

(h) Sampling

(1) Types of sampling

a) For the sampling of soil survey in a shallow foundation, BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) For the sampling of soil survey in a deep foundation and a site penetration test, BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

c) Sampling for non-dispersible specimen for clay and sand ground, BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

(2) Sampling of a disturbed specimen

a) When collection a disturbed sample, it should be put in a plastic bottle or vinyl bag and sealed while paying attention not to change the sample.

b) Sample should be collected from the borehole as a stratum is changed, and it should be carried out with a consistency within an identical stratum.

c) Sampling should ensure recording the name of investigation, date of sample collection, starting and ending dates of the boring, the number of borehole, investigation point, depth, sample number, thickness of the stratum, depth of the stratum change, condition of borehole after boring, ground water penetration location, special aspects during boring, and other references for the soil and rock tests.

(3) Sampling of an undisturbed specimen

a) Collection of sample shall be carried out according to Section called "Sampling of a disturbed specimen" at this section.

b) In case of using a static thin walled tube sampler, a piston rod or a chain should be completely fixed.

c) In advance of press-in of the sampler, the bottom of borehole should be cleaned.

d) The sampler press-in should carry out in a standard speed without interruption, impact, and vibration. The sampler needs to be inserted less than 90% of the effective length of sample collection.

e) It should be collected after completing the tube insertion without immediate rotation. During the drawing process, the sample disturbance (tension release) by suction should be minimized.

f) The samples collected through static piston thin wall tube should be sealed with paraffin, silicon powder, or other sealants, followed by applying a cap on it.

g) A tag showing the name of investigation, the number of borehole, the sample number, the insertion depth, and depth of the collected sample should be attached to the cap.

h) Any gap between the cap and the tube should be sealed using a tape.

i) The sample needs to be protected from extreme temperature change.

j) During transporting and storing the sample, the samples should be protected from damages and impacts.

(4) Test pit

a) The size of the test pit bottom is 1.0 m while the depth is deeper than 1.5 m. Access prohibiting facility or drainage should be installed if necessary.

b) The soil properties on the walls and bottoms of the test pit should be recorded, and a representative portion should be collected as a sample for a test.

c) After completing the test, the test pit should be refilled immediately in a compaction level exceeding the original condition. However, it may be exempted if a follow-up construction is scheduled with an approval of the construction supervisor.

d) The report should contain pictures showing the test process.

(5) Sample for an example

a) The collection location and quantity of the samples for an example should be determined by an engineer, and it needs to be approved by the construction supervisor.

b) The sample for an example should be put in a clear plastic bottle and sealed not to change the moisture content.

c) A label should be attached to the sample for an example, showing the name of investigation, the location of investigation, the number of borehole, the number of sample, the depth of collection, the name of soil classification, N value, and date of collection. No label needs to be applied on the surface of rock example, but a corresponding number should be shown on the rock with an appropriate way.

d) The sample bottle or box should be collected in an example box.

(i) Sounding

(1) Standard penetration test

a) For a standard penetration test, BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) Pay special attention to measure the test depth when a standard penetration test is carried out in a borehole. The construction supervisor may ask retests at a new location with a defined test depth including existing tests.

c) Unless specified otherwise, the interval of standard penetration test should be less than 1.0 m in continuity within an identical soil stratum. However, if the thickness of stratum is less than 50 cm, follow the direction of the construction supervisor.

d) Following items should be recorded on the test results.

1) The starting and ending depths of hitting during test

2) Depiction of the relationship between hitting numbers and accumulated penetration in a diagram

3) The preliminary penetration section (the upper 15 cm) should be excluded from counting as hitting number, N-value, since it is assumed as disturbed portion.
The number of hitting corresponding to 30 cm penetration should be recorded as the N-value.

4) Record the observation results of the collected sample.

(2) Swedish sounding test

a) Swedish sounding test shall be in conformity with SGF Report 1:93E.

b) Calibration results of the cone measuring instrument for the test should be submitted to the construction supervisor for an advance approval.

c) Relevant matters for test location, depth, and pore water pressure measurement should be consulted with the construction supervisor.

(3) Field vane shear test

a) For a field vane shear test, BS or other equivalent test standards may be employed after consulting with the Employer and the Supervisor.

b) Relevant matters for test location, depth, and pore water pressure measurement should be consulted with the construction supervisor.

c) The size of borehole for the field vane shear test should be determined after consulting with the construction supervisor.

(4) Dutch cone penetrometer

a) Dutch cone penetrometer shall be in conformity with JIS A 1220.

b) The corn tester should be of a double tube that is capable of measuring shear resistance and friction on the main face.

c) Results of zero-adjustment for the test corn should be submitted to the construction supervisor for approval.

(5) Piezo cone penetrometer

a) Piezo cone penetrometer shall be in conformity with ASTM D 5778.

b) When using a corn not specified in ASTM D 5778, it should be approved by the construction supervisor.

c) Results of zero-adjustment for the test corn's measurement components should be submitted to the construction supervisor for approval.

d) Relevant matters to the test location, depth, pore water pressure (including dispersion test) should be consulted with the construction supervisor.

e) When measuring pore water pressure of the ground, fully saturated Piezo corn should be used for the test.

(6) Pressuremeter test

a) Pressuremeter test shall be in conformity with ASTM D 4719.

b) The bore diameter of depth measurement should be drilled in a way appropriate to the outer diameter of the bearing portion with as flat finish as possible of the bore wall.

c) Test should be carried out as quickly as possible after boring in order to minimize the softening of bore walls arising from released underground stress and water move.

d) Each part of equipment should be checked, and rubber tension needs to be supplemented to ensure normal condition. The loading portion such as measurement tube is inserted to the specified depth.

e) Results of zero-adjustment for the test pressuremeter should be submitted to the construction supervisor for approval.

f) Relevant matters to the test location (depth) need to be determined after consulting with the construction supervisor.

(7) Water pressure test (field permeability test)

a) As a method to test rock permeability using water pressure, the water pressure test is applied to a ground reinforcement design and construction.

b) A curve for P (pressure)-Q (injection quantity) is prepared based on the water pressure test, and a permeability coefficient and Lugeon value are determined.

c) Flow patterns need to be figured out for each pressure step to judge the hydrological property of the ground.

d) In each pressure step, an identical pressure should be maintained for more than 5 minutes.

e) Each pressure step increases incrementally as 1, 3, 5, 7, 9 kgf/㎠ , and the pressure range may be adjusted by consulting with the construction supervisor.

f) The test sections may be distinguished into Single Packer, which the test is concurrently conducted with a boring investigation, and Double Packer, which the test is carried out after completing the boring investigation.

g) Each Packer method has its own merit and demerit so that determination of test method needs to be done with consultation with the construction supervisor.

(8) Shear test in borehole

a) This test is intended for finding rigidity integer of natural ground in a weathering zone

b) After attaching a shear plate on the bore wall, the shearing force is determined by applying a horizontal pressure and a vertical pressure in order. More, the disturbance to the borehole wall should be minimized for the boring investigation while conducting shear test directly on the borehole wall.

c) After tightly attaching the shear plate on the borehole wall, keep it intact for about 5 minutes.

d) Distinguishing the attachment pressures into 5 steps (5, 10, 20, 30 kgf/㎠), drawing tests are conducted for each pressure step. Two tests should be carried out for the identical pressure while rotating it 90° for the successive test.

(9) Image taking in borehole

a) As an imaging technique for the orientation of a surface of discontinuity, crushing zone, hazardous zone, and geographic boundary, it is further divided into the ultrasonic wave method and the optical methods.

b) For the ultrasonic wave method, water in the borehole is essential as the medium for sound wave propagation.

c) The optical method employs a micro camera that is inserted into the borehole for 360°image taking. Pay attention not to allow that foreign substances are drawn by the equipment when turbid boring water and a transparent tube insertion.

d) Square one calibration should be precisely done to measure the orientation of a surface of discontinuity, and the reliability should be secured comparing it to the actual core (adjustments of depth, direction, and slope)

(10) Water pressure crush test

a) Water pressure crush test shall be carried out by referring ASTM D 4645.

b) Water pressure crush test is carried out to find the initial bearing pressure of the object ground.

c) The initial bearing pressure is determined by crushing borehole with tensile force caused by water pressure after sealing a portion of the borehole with a expandable packer and applying water pressure to the section. The pattern of pressure fluctuation is measured while repeatedly applying and withdrawing pressure to the crushed section for the calculation.

2.9.3 Physical Prospecting

(a) General Scope

This specification shall be applied to the physical exploration intended for surveying ground properties required for construction execution.

(b) General Physical Prospecting

Physical prospecting and inspecting include the seismic profiling, the electrical exploration by electrical resistivity method, electromagnetic prospecting, radar prospecting, electrical and sonic wave inspections, and the object of investigation should be determined in line with the relevant construction objective.

Physical prospecting is intended for investigating the stratification condition and property of strata, thickness, and property of the surface soil or weathered stratum, property of ground and its surface appearance, location and dimension of crushing zone, location and dimension of cavity, and existence of ground water.

Electrical inspection is purposed to get more accurate soil column map and to confirm the properties of strata. Moreover, the sonic wave inspection is intended for calculating P wave and S wave propagation speeds and elastodynamic factors for each stratum.

An image of high resolution can be attained for detecting crushing zone distribution near a

tunnel or underground cavity when precise physical prospecting technologies are combined such as surface radar prospecting, borehole radar, or geotomography.

(c) Seismic Refraction Prospecting

The arrangement of lateral line may be modified depending on local condition after acquiring an approval from the construction supervisor as long as it does not interrupt the objective of survey.

The files at the middle and the end lateral line should be distinguished by size or color, and the relevant signs should be protected from damage. More, the Contractor should check the location and height of datum points.

The Contractor shall use and store test gun powder according to relevant laws and regulations, and it should be protected from theft.

Natural environment such as vegetation should not be damaged. Safety personnel should be arranged to prevent accidents during explosion, and signals should be made by siren or whistle to attract attention.

The explosion hole should be refilled with compaction.

When it is measured at two consecutive lateral points, it should be re-measured.

The measurement results should be summarized in the lateral line arrangement drawing, the time-distance curve, and the cross sectional diagram.

Interpretation details should be clearly expressed on the time-distance curve and the cross-sectional diagram.

When a hammer hitting is used due to local condition, it should be applied considering effective depth for detection (detectable depth) and resolution while minimizing noise to the surroundings.

(d) Electrical Exploration

The arrangement of lateral line may be modified depending on local condition after acquiring an approval from the construction supervisor as long as it does not interrupt the objective of survey.

The arrangement of electrode should be set in line with the exploration goal, and the interval of electrode may be determined appropriately according to the ground depth and electrode arrangement.

The maximum electrode interval should be determined according to the exploration depth.

Unless it is not available due to local conditions, the electrode needs to be progressed in the perpendicular direction of the main direction of anticipated geological structure.

Measurement should be checked by Plot to the resistivity electrode interval curve (ρ-a) or by the control computer, and it should be re-measured by switching electrodes when differentiated values are obtained.

The results of exploration should be summarized as the apparent resistivity curve in cases of the lateral line arrangement drawing and the vertical exploration while the results are summarized as the apparent resistivity cross section diagram in case of double electrode arrangement resistivity exploration. Other analytical results should be arranged in the resistivity isodose line drawing.

(e) Electromagnetic Prospecting

Electromagnetic prospecting may be used to yield the identical resistivity cross sectional information at locations that application of the electrical exploration in Section 3.3 is obstructed such as concrete or asphalt pavement or that inadequate contact of electrode to the earth.

The Contractor should consult with the construction supervisor for the equipment and method before the prospecting, and the results of measurement should be submitted to the supervisor.

The Contractor may change the setting, interval, and total length of lateral line and the interval of the lateral point after acquiring approval of the construction supervisor as long as such change does not obstruct the investigation purpose.

(f) GPR Prospecting

GPR prospecting may be used to search a buried object or to confirm geological features such as heterogeneous zone or crushing zone.

The prospecting makes measurement while moving two transmitting and receiving antennas that are arranged with a certain distance along with lateral line incrementally.

The Contractor shall submit a sectional radar cross section report, which is yielded by computer numeric scale modeling (computerization) of the GPR data, to the construction supervisor.

(g) Electrical Inspection

Excepting the casing insertion area and non-measurable section arising from electrode arrangement, the electrical inspection should be carried out for the entire section.

Electrical inspection should be carried out for both resistivity and self-potential.

Resistivity measurement is done by the double electrode electrical inspection method in principle. The intervals of electrodes should be 25 cm, or 50 cm, or 100 cm, or other distance with the equivalent accuracy.

The records on the lateral line should be done continuously, and the measurement distance should not exceed 50 cm even when the continuous record is not carried out.

When the measurement is impossible due to collapse or etc., the direction of the construction supervisor should be observed.

(h) Sound Wave Inspection

Excepting the casing insertion area and non-measurable section arising from ground water distribution, the sound wave inspection should be carried out for the entire section.

However, the casing insertion needs to be measured if it can be displaced.

The borehole receiver and the start short receiver are used for the receiver, and the borehole receiver should be able to measure one vertical component and two horizontal components.

The direct noise arising from surrounding traffics should be avoided for the measurement.

When the measurement is impossible due to collapse or etc., the direction of the construction supervisor should be observed.

When the diameters of the borehole are significantly different, the Contractor should conduct Boreholes Compensated (BHC) sonic wave inspection that mitigates the impacts of borehole diameter on the velocity by employing more than 2 sets of receivers and transmitters.

(i) Geotomography

Geotomography uses two or more boreholes, in which a transmitting body radiates an elastic wave or electromagnetic wave (radar) to the surrounding medium, and produce images of physical property distribution such as velocity of medium, absorptiveness, or resistivity in 2D or 3D by back calculating the matrix of measured data after measuring propagating wave travel time or amplitude through diverse paths in between two boreholes.

In case of the resistivity tomography, an image of cross sectional resistivity is produced through 2D numeric back calculation after arranging appropriate electrodes to the prospecting purpose.

In case of the electromagnetic prospecting tomography, an image of cross sectional resistivity is produced through reverse calculation of refraction tomography after setting appropriate frequency and measurement distance in line with the object resolution.

Ray Tomography or refraction tomography may be used for Geotomography, and the Contractor should submit the final report to the construction supervisor.

(j) Seismic Prospecting of Borehole Space or Downward Seismic Prospecting

Seismic prospecting of the borehole space is intended for measuring the elastic wave speed (P and S waves) for each depth of the local rock while the downward seismic prospecting is intended for distinguishing rocks and calculating the elastic dynamic factor by measuring velocity for each section according to the relevant depth.

The interval of measurement should be set appropriately according to the local rock condition and the prospecting goal.

S-waves with polarity in the opposite directions are generated for the Seismic Prospecting of Borehole Space or Downward Seismic Prospecting while the S-wave returning time is precisely read by analyzing the amplification and position of S-wave.

Crevice measurement must be conducted for the seismic prospecting of borehole space, and the distance between the receiver and the transmitter should be calculated precisely.

2.9.4 Survey for Condition of Location

(a) Topographic Survey

Influential topographic features need to be analyzed using design documents, topographic map, or aerial photographs, and it should be investigated by site survey.

Unstable geographical features and locations with anticipated disaster, such as Talus, collapsed region and landslide area, and damage area by flood, must be investigated.

(b) Environmental Survey

The environmental survey for the project area and its vicinities performed during designing phase should be repeated at the phase of construction.

The environmental survey is intended for estimating environmental changes arising from construction, establishing environmental preservation measures, and confirmation of their effectiveness, including followings.

(1) Surface and ground water: Conditions of water use, water resources, ground water flow, and possible level changes

(2) Noise and vibration: Potential impacts by noise and vibration

(3) Deformation of ground and structures: Construction with potential impacts on the building, structure, topography and geological features, and deformation of a structure

(4) Disaster: Potential locations and degree of damages from landslide, collapse, earthquake, and flood

(c) Survey for Underground Obstructive Features

Safety construction should be ensured by grasping types, sizes, and depths of existing underground facilities including water supply and sewage pipelines, power and communication cables, underground shaft, and other obstructive features.

For a boring investigation, a map for underground facilities should be acquired from the relevant authority, and their existence needs to be checked by an excavation or physical prospecting. Boring should be done in collaboration with the relevant authorities.

The investigation results need to be maintained to be utilized to protect them for the follow-up construction.

(d) Survey for Spoil Area

When a spoil area is needed to treat waste generated during construction, conditions for transportation need to be investigated including relevant topography, transportation means and distance, traffic regulation of the transportation road, and traffic safety.

Investigations should also be conducted for environmental impact on surroundings, soil change after spoiling, and legal regulations.

(e) Survey for Construction Facilities

Construction facilities are further divided into the ventilation and dust collection, transportation, aggregate and concrete plant, power supply and distribution, water supply and sewage, and temporary buildings.

Following aspects need to be investigated to establish a plan for construction facility.

(1) Topography, geological feature, and climate: Topography, geological feature, and climate with potential of deteriorating facility performance

(2) Surrounding environments: Impacts on surrounding environment arising from noise, vibration, drainage, and traffic flow of the construction equipment

(3) Use of electric power: Capacities of existing and new power cables, frequency, voltage, difficulties in power distribution and supply, required time for power supply, generator, and power consumption for operating construction equipment

(4) Water supply and drainage: Water for compressor, for concrete mix, drinking, and water intake condition for other miscellaneous water uses, treatment of construction water, and discharge conditions for the cleaning water

(5) Transportation of materials and low-grade ore: Access of machineries and materials, construction road to transport the low-grade ore, standard for rails, traffic volume, safety, and conditions of traffic regulation

(6) Construction material: Aggregate for concrete relevant to the construction facilities, not cured concrete, supply channels of other materials, conditions of suppliers and their management, and nearby constructions

(7) Legal and other regulations: Nearby construction

(f) Survey for Compensation

Before the construction commencement, every aspect for compensation should be investigated in details.

Subjects of compensation should include land, building, and vegetation acquisitions for the construction lot, migration of them, violation of various rights (surface right, subsurface right, water right, mine right, and stone quarrying right), decrease of farm profit, and loss of sales.

2.10 METAL WORK AND MISCELLANEOUS FITTINGS

2.10.1 General

The Contractor shall be responsible for the detailed design of all items covered by this section of the Specification and their correct performance. The items shall adhere to the general arrangements indicated on the drawings and be to the approval of the Engineer.

The work shall be prefabricated for site assembly without welding. All bolts and nuts shall be assembled with one washer under the head of the bolt and with another washer under the nut. All bolts, nuts and washers shall be galvanized or sheradised.

The Contractor shall submit to the Engineer for his approval number of copies of detailed drawings and specifications which is made through discussion with the Employer and Engineer for all items to be specially fabricated or tailored for the Works and number of copies of manufacturer's drawings and specifications is made through discussion with the Employer and Engineer for standard items. The Contractor shall furnish additional information and calculations if requested by the Engineer.

The Contractor shall allow three weeks for the Engineer to check the details, from receipt by the Engineer of complete information. No items shall be manufactured or ordered from suppliers until the Engineer has signified his approval of the details.

Subsequent to approval being given, the Contractor shall submit a further number of copies of the drawings, specifications and other information which is made through discussion with the Employer and Engineer to the Engineer. Drawings and specifications which have been approved by the Engineer shall not be departed from without approval of the Engineer.

2.10.2 Structural Steel Work

Material for structural steelwork shall comply with BS 4360 and workmanship with BS 449. The steelwork shall be securely fixed to the foundations or buildings and designed to have such strength and stiffness that its deflection and movement under the loads to be applied shall be within tolerable limits.

All bolts and nuts shall comply with BS 3693 except for High Strength Friction Grip Bolts which shall comply with BS 4395.

Mild steel electrodes shall comply with the requirements of BS 639 and High Yield Steel with BS 2540.

All structural steel fabrication shall conform to the requirements of BS 153. The use of High Strength Friction Grip Bolts shall be in accordance with BS 3294.

All structural steelwork shall be hot dipped galvanized after fabrication and shall be fabricated using welded joints where possible for shop joints and bolted joints for field assembly.

Alternatively, structural steelwork may be designed in accordance with the American Institute of Steel Construction Specification for the Design Fabrication and Erection of Structural Steel for Buildings, 1969 Edition and the American Institute of Steel Construction Code of Standard

Practice for Steel Buildings and Bridges, 1972 Edition.

2.10.3 Open Mesh Walkways and Covers

Open mesh type walkways, platforms and covers shall be of aluminum or galvanized steel, suitable for a superimposed load of not less than 6kN/m2 and shall comply with the relevant provisions of BS 4592: Parts 1, 2 and 3. They shall be provided with suitable angle kerbing frames fixed to the structural steelwork or concrete (using appropriate tangs cast-in) as appropriate. The kicker plates, for safety purposes, shall also be provided as appropriate.

The walkways, platforms and covers shall include all necessary supports not detailed on the Drawings.

Open mesh panels shall be trimmed with full depth nosing bar along all edges and bolted to each other when in place to help ensure a firm walkway. Panels shall be cut in such a way and fixed so as to provide a continuity of pattern.

Covers shall incorporate a hinged and lockable open mesh access panel with strong durable hinges and heavy duty non-corrodible padlock. Openings for valve keys shall be just sufficient in size for the valve key and shall incorporate a cover hinged only.

All panels shall be securely bolted to the supporting structure. Where the supporting structure is concrete, galvanized mild steel angle curbs shall be provided and securely grouted into rebates left in the concrete such that the tops of the panels are flush with the top of the concrete.

All steelwork shall be hot dipped galvanized after fabrication.

2.10.4 Metal Covers (Top)

(a) This specification is applied to production and installation of various metal covers having iron, non-iron metal, and their secondary products as the main material.

(b) The Contractor should provide and fix 6mm sheet metal access cover with 40x40 angle iron farm with latch and safety lock for valve chamber and reservoir (1.65x2.5) or by drawing.

(c) For the materials for exposed surface metal products, color, surface treatment, painting condition, and durability should be approved by the construction supervisor by submitting required data asked by him/her about the sample product designated by him/her, product data supplied by the manufacturer, and test records.

(d) Every product should be protected from corrosion, deformation, or damage and stored without making a contact with soil or air directly. Any damaged one shall be replaced by a new product. In case of a steel product, the corrosion protection should not be damaged.

(e) The welding rod should be kept in a dry condition, ensuring not to expose it in a high humidity condition. The sheath of rod should not be delaminated by an impact.

(f) Every steel product should be painted with a red lead mixed paint in conformity with BS after priming. However, it may be exempted when the product does not need separate anti-corrosion paint since it is galvanized or powder coated.

(g) Appropriate leakage prevention should be applied for locations with possible storm water penetration such as manhole during production, and accurately fitting neoprene gaskets should be used as specified in drawings.

(h) Manhole cover

(1) Cast iron should be used for manhole to ensure sufficient rigidity to exterior impact, and the shape and size are to be in accordance with the manufacturer's specification, drawings, or construction specification.

(2) If letters are engraved on the cover, it should be in conformity with the direction of construction supervisor.

(i) Access Hole

(1) The stainless steel plate for a stainless access hole shall be cold rolled stainless steel plate with a hairline finish

(2) The steel plate for a steel access hole shall be hot-dip galvanizing steel plate (General Purpose).

(3) For hinged access hole, a rubber packing with a size of φ12 mm should be used to prevent impacts by opening and closing.

(4) The frame hardware for supporting access holes should be installed with reinforcement to prevent deformation or damage by vertical load.

(j) Trench Cover

A trench cover should bear the larger stress between an uniformly distributed load of 1,220 m^2 kg/ for a direct load of 3,628 kg.

(1) Steel trench cover

a) Material, shape, and size of the steel trench cover shall be in conformity with the product data of a certified manufacturer Galvanized steel product with bar-type shall be used.

b) The frame hardware for trench should be galvanized steel and installed with reinforcement to prevent deformation or damage by vertical load.

(2) Stainless steel trench cover
The material of stainless steel plate should be in conformity with BS with a thickness of 3 mm or over. Punching hole should be made as specified in drawings to install the frame anchor hardware rigidly. Slippery preventing surface treatment should be done on the surrounding trench cover and others.

(k) Entrance Cover

(1) A rigid entrance cover should be installed according to drawings.

(l) Subsidiary Materials

(1) Joint metal
Every fixing metal should be of non-corrosive material or with an anti-corrosion coating with appropriate size, strength, and material in line with the purpose.

(m) Construction

(1) Installation

a) The anchor plate should be installed at accurate point rigidly. If the location is not accurate or if the installation is defective, a correction should be made after acquiring approval to ensure the equivalent performance with the original one.

b) It should be installed with accurate vertical and horizontal levels, and the steel door needs to be welded on the foundation anchor.

c) Frame hardware should be supplemented rigidly for corners or a overlapped section according to the direction of the construction supervisor.

d) Paint may be applied before installation when it is hard to be done after installation. Any damage on the concrete surface or anti-corrosion coating should be repaired before installation. Construction and installation order may be adjusted not to deteriorate the powder coated portions by site welding.

(2) Field Quality Management
Installation conditions should be inspected after completion. Any color change, contamination, or damages identified during the inspection should be immediately repaired. If repair is not easy, it should be replaced and reinstalled.

(3) Cleaning the installation site

a) Cleaning and protection
Every exposed surface metal finish material should be protected by using appropriate protection medium in line with material and construction process until the completion of the project to prevent color change, contamination, and damages by other type of construction work.
The protective medium should be removed upon the project completion and cleaned.

2.10.5 Galvanizing

Where galvanizing has been specified the items shall after fabrication be hot dipped galvanized in accordance with BS 729, or where approved zinc coated in accordance with BS 2569 Part 1 to a thickness of 0.15 mm (0.006").

All items to be protected shall be prepared as specified in the above standards.

Articles altered at the manufacturers works in any way after galvanizing are to be regalvanized as specified.

Articles subject to minor alterations on site or requiring minor repair on site shall be wire brushed to remove all rust and coated with 3 coats of approved zinc rich cold galvanizing compound.

2.11 SCAFFOLD

2.11.1 Materials

(a) General

(1) The material of Scaffold shall be used in accordance with international equivalent standards such as ASTM.

(2) Structural steel shall be used for scaffold.

(3) The material for scaffold shall be uniform in section and sectional modulus, and shall have rigidity demanded on construction detail drawings.

(4) Materials being deformed, corrosive and being severe damaged shall not be used.

(5) Materials for scaffold shall be in accordance with construction specification. And in case that there are no problems with the material in structural function, performance, and in feature, the material can be reused.

(b) Steel pipe scaffold

(1) Steel pipe scaffold shall be conformed with the regulation for performance test for temporary facilities.

(2) Floor for pass way shall be conformed with the regulation for performance test for temporary facilities.

(3) Clamp shall be conformed with the regulation for performance test for temporary facilities.

(4) The supporting miscellaneous metals of steel pipe scaffold shall be conformed with the regulation for performance test for temporary facilities.

(5) Wall connection metals shall be conformed with the regulation for performance test for temporary facilities.

(6) In case of using special metal, it shall be confirmed that the metal withstands the imposed stress.

(c) Fabricated scaffold

(1) Fabricated scaffold shall be conformed with the regulation for performance test for temporary facilities.

(2) Working stage shall be conformed with the regulation for performance test for temporary facilities.

(3) Support metals for fabricated scaffold shall be conformed with the regulation for performance test for temporary facilities.

(4) Wall connection metals shall be conformed with the regulation for performance test for temporary facilities

(d) Transfer platform

(1) Transfer platform shall be conformed with the regulation for performance test for temporary facilities.

(2) Wheel for moving scaffold shall be conformed with the regulation for performance test for temporary facilities.

(3) Supporting metal for transfer platform shall be conformed with the regulation for performance test for temporary facilities.

2.11.2 Execution

(a) Execution – General

(1) Construction of scaffold shall be done according to construction plan and drawings.

(2) Construction work shall be done such that suitable method and materials are used in consideration of construction type, size, location so as to be safe and convenient to proceed execution.

(3) Working platform shall be fixed tightly to joist.

(4) In case that the electric cable is adjacent to scaffold, adequate action shall be done not to be damaged.

(5) For weak ground, compaction, concrete placing or laying plate with thickness more than 45 mm shall be done in order not to be settled of column of scaffold.

(6) The connection of columns for more than 3 columns shall be done. If the support metal has been fixed at the bottom foundation, the connection can be omitted.

(7) Scaffold shall not be installed on frozen ground without any alternatives for thawing.

(8) To avoid overturning or buckling of column scaffold shall be fixed to the structure with connection metals.

(9) Connection is done at the cross point between horizontal direction member and vertical member.

(10) For unfolding of the connection, it shall be done by partly sequence.

(b) Construction of steel pipe

(1) The column of scaffold shall be such fixed tightly with brace or horizontal member as not to move or shake.

(2) Column of the scaffold shall be laid on strong foundation to transfer the imposed loads.

(3) The intervals between columns of scaffold shall be smaller than 1.8 m for the wale direction and 1.5 m for joist direction.

(4) In case that the height of column exceeds 31 m, a steel pipe is used at the higher portion than 31 m and tied 2 steel pipes at the lower portion than 31 m in consideration of buckling.

(5) The imposed load at a column shall not exceed 6.8 kN (700 kgf).

(6) The space between wales shall not exceed 1.5 m in vertical, for the first wale from the ground the space can be 2 m for the pass way if buckling does not occur.

(7) In the case that the wale is installed continuously, lapped splices is used and the distance between wales provided lapped splices shall be 100 mm or less, and for the connection between staggered column clamp shall be used.

(8) The location of splices shall be staggered more than minimum 300 mm.

(9) Space between joists in vertical shall be less than 1.5m, and tied with column of staging at cross point between column and whale, and tied with whale at mid-point.

(10) In case of butt laying with work stages, the working stage of joist shall be installed so as that the overhanging portion shall be 100 mm up to 200 mm.

(11) Joist shall be installed so as the overhanging portion to be more than 50 mm.

(12) Diagonal brace shall be installed at an angle of 400 or 600 from horizontal and shall be tied to column or wale, and the space of the brace shall to be crossed at every 15 m.

(13) Cross point between brace and column of scaffold shall be tied with rotational type clamp.

(14) The horizontal brace will be provided at every span, at the height of attached wall metals.

(15) Connection between walls shall be installed at the maximum interval of 5 m for vertical and horizontal, respectively.

(c) Prefabricated scaffolding

(1) In case that total height exceeds 20 m and heavy weight work, the interval of the main frame shall be 1.8 m or less.

(2) The limit of imposed loads is 3.92 kN (400 kgf) for 1.8 m interval of main frame. In case that the interval of main frame is less than1.8 m, load limit can be increased by ratio. If the foundation is firm, the limit of vertical load will be 24.5kN (2,500 kgf) per column.

(3) In case that the passway, entrance, and opening is safe enough for imposed loads, the height and interval of main frame can be increased.

(4) The bottom of the column member of main frame shall use supporting metal and shall be laid on firm foundation in order to transfer the imposed loads to the foundation safely. In case that the foundation is uneven, support metal shall be used for correction.

(5) Wale frame and horizontal member shall be installed at the top of main frame and at every five stages of main frame.

(6) At the edge of scaffold, main frames shall be tied with steel pipe and clamp, and for the opening guardrail shall be provided.

(7) Cross brace shall be provided at every stage and span and the tied portion shall not be failed due to the vibration.

(8) In case that a part of cross brace is removed, horizontal member or wale frame shall be provided instead. But the cross brace at the stage of wall connection shall not be removed.

(9) Wall connection shall be installed 6 m and less in vertical direction and 8 m and less in horizontal direction. In case that the height of scaffold exceeds 4 times of the length of bottom, wall connection shall be provided at every height of 4 times of bottom length with connection metals.

(d) Transfer platform

(1) Prior to fabricate the transfer platform, structure, strength, function, and materials shall be inspected carefully, if there is any defects.

(2) The height of transfer platform shall not exceed 4 times of minimum width of bottom.

(3) In case that the platform is more than three stage, support structure shall be installed or shall be fixed to the structure to prevent from overturning and shaking.

(4) Guardrail shall be provided at top platform and connection area, cross connection area shall be inspected not to be failed while a work.

(5) In case that the guardrail has been removed for work unavoidably, guardrail shall be installed just after the work.

(6) Break system at wheel shall be provided and it shall be in operation always except moving period.

(7) At inclined slope the working platform of the main frame shall maintain level by using jacks.

(8) Another supports or ladders shall not be used on working platform.

(9) Any concern for droppings, protection roof shall be provided.

(e) Inspection scaffold

Prior to work on the scaffold, inspection shall be done by using inspecting sheet. Any defects founded, scaffold shall be maintained immediately.

(1) Inspection before and after fabrication

- Confirm the materials comply with standard and regulation.
- Confirm any defects due to corrosion, deformation, damage
- Inspect the conformation with installation drawings.

(2) Inspection at bad weather

- Inspection before bad weather

a) Immediately after a strong-wind warning, check wall connection metals, support timber, and so on. If necessary, prevention shall be done for tilting and failing of scaffold, material scattering.

b) Remove or prevention action for protection screen for falling, guard net, boards.

c) Check wall connection, the location of members. If necessary, provide timber support.

- Inspection after bad weather. Check the followings.

a) Check the dropped material on platform.

b) Electric wire.

c) The condition of working boards.

d) The column foundation.

e) Fastened condition of wall connection and clamp

(f) Removal scaffold

(1) Prevention for collapse, falling, drop shall be provision, prior to disassemble and removal.

(2) All scaffold for construction shall be removed until construction completed.

(3) All separated members and connection metals shall not be dropped from scaffold. Remaining structures shall be stable during removal scaffold.

(4) Wall connection metals had better remove later. Especially, the wall connection metal in area which safety facilities are exist shall be removed carefully. If necessary, auxiliary facilities shall be provided.

(5) During removal scaffold the surfaces of buildings and structures shall not be damaged.

(6) The location of joint of column and the removal sequence shall be checked prior to remove the columns and wales.

2.12 STAGING

2.12.1 Materials

(a) General material

(1) The material of Staging shall be used in accordance with equivalent standards or regulations to the British Standards

(2) Steel pipe staging shall conform to BS Steel pipe supporting column.

- Inner and outer pipe for supporting column shall conform to BS.
- Other materials besides pipe shall conform to BS.
- The materials for screw and ring shall conform to BS.

2.12.2 Execution

(a) Staging installation

(1) All base line, leveling, elevation shall be established in order that all staging should be installed at exact location. The Contractor shall be responsible for the accuracy of all geometric data related to staging installation.

(2) The type of staging shall be suitable for the function of staging which transfer the imposed loads to the foundation.

(3) Arrangement of staging shall be suitable for installing and removal and the loads shall be transferred safely at joints and connections.

(4) The method of constructing staging shall designed so as not to occur the settlements and the staging has a capacity of supporting the loads shown in drawing which is approved by supervisor.

(5) The staging shall be safe for erosion of foundation, prevented from soil being weak and the loads imposed shall be supported by foundation. The bearing capacity of the foundation shall be conformed that the estimated bearing capacity does not exceed the actual capacity by testing foundation at site.

(6) In case that the staging supported by piles, pile driving shall be done until the piles have the sufficient bearing values, the bearing value shall comply with the value shown on drawings.

(7) If the staging is adjacent to road or cross over road, additional structures shall be provided to resist with impact from road, and the added structures shall not be removed until the staging being removed.

(b) Camper correction

(1) In case of the Engineer's approval, camper strip shall be used to correct the deflection of staging and the expected deflection of structures.

(c) Settlement

(1) To measure the entire settlement of structure, auto display sensor shall be installed at the form adjacent to ground so as to read easily.

(2) Additional dead load shall not be loaded on the staging without supervisor's approval.

(d) Removal staging

(1) The Contractor shall be approved by supervisor prior to the removal of any staging.

(2) To determine the staging removal, the Contractor shall submit the structural calculation or reviewed report, and test result of concrete to the supervisor.

(3) The sequence of removal shall be such detail as to ensure that the imposed loads will be uniformly distributed to the members.

(4) Except in the case of supervisor's special approval, the piles shall be pulled up and the pile foundation area shall be restored to the original state.

(e) Quantity estimation and payment

(1) For quantity estimation, the boundary line is bottom line and exterior line of the concrete member, and the estimation unit is space m^3 and the detail guide for estimation is as followings.

- Slab at bottom : the space to the bottom of the slab.
- Embankment or excavation : the space to the design ground level.
- No earth work : the space to the original level.

(2) Payment will be done by space m^3 unit in detail estimate sheet of tender document. Following expenses is included in payment.

- Materials such as container of staging, bracing, material such as binding wire.
- Expense of preparation for staging installation.
- Staging installation, removal and finishing work.
- Other works for staging.

2.13 WATERPROOF WORKS

2.13.1 Execution Waterproof : the inside

The Contractor shall provide the material which is made through discussion with the Employer and Engineer for the inside waterproofing.

(a) General

This specification is epoxy waterproof way to prevent corrosion or waterproof

(b) Reference Standards

Followed by the relevant BS.

(c) Material

(1) Primer and Epoxy Waterproof paint

(2) Basis control material (degree of attachment strength is more than 150 N/cm^2)

(3) Inspection mechanism (thermometer, hygrometer)

(4) Quality testing (practice 1 time by BS provision)

(d) Construction

(1) Drying thickness is to become 0.7 mm.

(2) After painting basis control material, practice at least 24 hr.

(3) epoxy waterproof layer practice divided twice and finishing layer is the blue.

(4) Total drying thickness is 0.5 mm.

(5) Second coating practice at least 24 hr.

(e) Cleaning and protection.

2.13.2 Waterproof : the outside

(a) General

Using rubber asphalt based material, it is the method of the waterproof for the construction.

(b) Material

- The rubber asphalt waterproof agent should be suitable the British Standard
- The reinforcing agent for enhancing the waterproof layer as a material of glass fiber, synthetic fibers, woven or nonwoven fabric is used.

(c) Construction

(1) Arrangement

- Construction floor remove impurities
- The bad part broken is filled with waterproof mortar with V-cut.

(2) Primer coating

- Apply many times thinner by brush or roller

(3) Material mixing

- Put forward solvent of the material during mixing, Mix 3-5 minutes to put the later curing agent

(4) Coating

- Working twice, become total thickness 2 mm or more using the brush
- Hardens reinforcement Insertion is to prevent the occurrence wrinkles before the lower layer

2.14 WATER STOP

2.14.1 Water Swelling Rubber Water Stop

Water swelling rubber water stop shall be in conformity with the relevant standards.

Installation surface for the water stop shall be maintained in a clean and dry condition.

The overlapped water stops for joining shall be about 50 mm.

2.14.2 PE Water Stop

The water stop shall be in conformity with Polyvinylchloride Water stop that can seal concrete joints effectively against moist penetration with sufficient rigidity and elasticity.

The water stop shall be produced through a process ensuring dense and uniform material distribution without any pores or other foreign substances. The cross section of the water stop shall be uniform and symmetric throughout the entire length.

The water stop shall be installed at the location as specified in the design document without any twist or bend, and the water stop joint shall be done without any leakage by PVC welding or other methods that have been approved by the Supervisor.

When concrete is applied on the water stop, every foreign substance shall be removed including oil, grease, and dried mortar while filling every portion of the water stop with concrete densely and rigidly.

The water stop shall be installed at every installation and joint on the exterior wall, floor slab, and other specified location.

The water stop shall be installed accurately in its place and fixed not allowing any movement by slightly burying it during concrete application or by other appropriate methods.

The water stop shall be installed to have the same buried portion relative to the both sides of joints.

The water stop shall be installed in a longest possible length, and the waterproofing seal shall be continuous throughout the entire length by appropriate joining.

Concrete shall be applied and compacted in between concrete and the water stop to ensure complete filling and adhesion.

Any damaged or defective or inappropriately installed water stop shall be repaired or replaced by the guidelines of manufacturer.

Water stop shall be joined using an electric heater with temperature regulating function and welding material according to the joining guidelines by the manufacturer. The joint shall have a tensile strength that is 60% of the original material or above with continuity of the water stop and pores. If the water stop joining is obstructive due to field conditions, it should be connected in a way that the waterproof is maintained by using connective material designated by the manufacturer.

Site quality management: The water stop and its joints shall be inspected to check whether there is any defect that can deteriorate the water proof installation effect arising from faulty installation, bubbles, inappropriate adhesion, permeability, cracks, or dislocation or not.

2.15 DRAINAGE AND SEWER WORKS

2.15.1 General

This specification covers general requirements for drainage and sewer work.

2.15.2 Reference Standards

- Reference Standards for drainage and sewerage works shall follow the Design Standards and detail codes described in Sub-section 1.1.3. All work in this section shall be carried out in accordance with locally applicable standards and codes of practice for material and workmanship or applicable codes and standards.
- Related construction specifications shall comply with the requirements indicated in the following construction specifications described in sub-sections for “2.2. Earth Works” and “2.3. Concrete Works”.

2.15.3 Materials

- Concrete pipes, and clay pipes shall confirm to local standards. The contractor shall submit catalogue of pipes and samples for approval of the engineer.
- All pipes shall also be provided with specials such as elbows, bends, y-branching, T-branching etc. which shall be of same material and diameter as the pipe.
- Cracked or chipped or damaged pipes shall be rejected. Such rejected pipes shall be immediately removed away from site by the contractor. The contractor shall not be entitled to claim any compensation (monetary or otherwise) arising out of such rejections.
- Cement and sand shall be of the same quality as of construction specification for Concrete Works.
- The other pipes shall be approved by the engineer.

2.15.4 Execution for Concrete Pipes

(a) Installation

a) Excavation for pipe trench shall be carried out in accordance with Construction Specification : “2.2. Earth Works".

b) Removal of Unsuitable Material
Where wet or otherwise unsuitable soil incapable of properly supporting the pipe, as determined by the engineer, is encountered in bottom of trench, such material shall be removed up to the required depth and replaced to the proper grade with selected material and compacted as provided in the specification.

c) Temporary bridges or crossing shall be built or erected in position by the contractor where required to maintain traffic and movement of material and personnel at no extra cost to client.

d) Bell holes shall be excavated accurately to size by hand.

e) Pipe Bedding.

The bedding surface for the pipe shall provide a firm uniform pipe bearing support throughout the entire length of pipe.
Lean concrete of grade fc = 16 MPa at 28 days age shall be laid for bedding where the quality of soil is poor in compaction. However, lean concrete shall not be necessary where the quality of soil is suitable for tamping and consolidation to the required profile.
The pipe shall be carefully in the wet laid concrete or in soil, accurately rounded to conform to the lowest on fourth of the outside circumference of the circular pipe when necessary, the bedding shall be tamped.

Associated formwork for lean concrete bedding shall be carried out by the contractor if necessary at no extra cost to Customer.
Bell boles and depression for joints shall be of such length, depth and width as required for properly making the particular type joint as applicable.

f) Pipe Laying and Handling
Pipes shall be protected during handling against impact shocks and free fall. Proper facilities shall be provided for lowering the sections to prevent disturbance of the bed and trench sides.
All bends and special fixtures shall be laid along with the pipe as per drawing.

g) Pipe Joints

- Bell and spigot concrete pipe ends shall be thoroughly cleaned of all dust and undesirable matter and made wet.
- Jute fiber hemp rope shall then be dipped in thick cement slurry.
- The straight end of consecutive pipe shall be inserted in the bell mouth of previous pipe as required and shall be aligned by supporting on previously formed bedding.
- Jute fiber hemp rope thoroughly soaked in thick cement slurry shall then be inserted in between space of bell mouth and straight end of pipe in the form of a ring and caulked with caulking tools and a small chisel until the entire space is thoroughly packed with jute hemp rope.
- Cement mortar of 1 part cement : 2 parts of sand by volume shall then be thoroughly caulked in the space and finished smooth on all along the outer diameter of bell mouth as per drawing with sloped ends to repel any water. Water quantity in the mortar mix shall be such that the consistency of the mortar is suitable for the purpose intended and to the satisfaction of the engineer.
- Completed joint shall then be allowed to harden or set and cured with clean water without disturbing the joint for at least 5 days.
- Alternately concrete pipe joints shall be caulked with elastometric ring gasket which shall be inserted in place of jute or fiber hemp rope and caulked and sealed with either cement mortar or manufacturer approved sealant in the similar way as mentioned above.
  The size of elastometric ring gasket and the material quality shall be as recommended by the manufacturer.

h) Pipe joints at shallow depths shall be protected by a concrete sleeve pipe twice the outer diameter of be 11 mouth of pipe, or by covering the joints with extra thickness of 100 mm thick plain cement concrete as indicated in the drawing or as instructed by the engineer.

(b) Testing

a) The whole or part of underground drainage pipeline system shall be hydrostatically tested at the completion of work to the satisfaction of the engineer and other authorities and shall be retested if necessary until approved.

b) The pipe line shall be hydrostatically tested between manholes or free ends. Short branches between manholes shall be tested as one system with the main drainage line.

c) Lower ends and ends of connections shall be temporarily plugged. Water shall be added during test to compensate for absorption, and the test shall be continued for as long as the engineer may direct.

(c) Backfilling

a) Backfilling of pipe trenches shall not be commenced until after the pipes therein have been tested and passed to the satisfaction of the engineer.

b) Backfilling shall be carried out in layers not exceeding 300 mm, of un-compacted thickness.

c) Compaction density of backfilled soil shall not the less than 95% of maximum dry density of soil when backfilling is carried out for trenches below paved roads, paved areas and adjacent to existing structures.

(d) Test Certificates

When the entire underground pipeline is successfully completed, tested, inspected and approved by the local authorities having jurisdiction over such work, the contractor shall obtain a test certificate from such authorities and shall pay all the necessary fees and taxes as stipulated by the local authorities and shall submit such a certificate in three copies to the engineer certifying that the work has been carried out to comply with regulations approved by the local authorities.

2.15.5 High Density Polyethylene (HDPE) Pipes

(a) Except where otherwise specified, High Density Polyethylene pipes and fittings shall be in accordance with the following standards :

ASTM D 3350	Standard Specification for Polyethylene Plastics Pipe and Fittings Materials
ASTM F 1055	Standard Specification for Electrofusion Type Polyethylene Fittings for Outside Diameter Controlled Polyethylene Pipe and Tubing
ASTM F 1281	Standard Specification for Crosslinked Polyethylene / Aluminum / Crosslinked Polyethylene (PEX-AL-PEX) Pressure Pipe
ASTM F 1282	Standard Specification for Polyethylene / Aluminum / Polyethylene (PE-AL-PE) Composite Pressure Pipe
ASTM F 1962	Standard Guide for Use of Maxi-Horizontal Directional Drilling for Placement of Polyethylene Pipe or Conduit Under Obstacles, Including River Crossings
ASTM F 2206	Standard Specification for Fabricated Fittings of Butt-Fused Polyethylene (PE) Plastic Pipe, Fittings, Sheet Stock, Plate Stock, or Block Stock

ASTM F 714	Standard Specification for Polyethylene (PE) Plastic Pipe (SDR-PR) Based on Outside Diameter
ASTM F 810	Standard Specification for Smooth wall Polyethylene (PE) Pipe for Use in Drainage and Waste Disposal Absorption Fields

(b) High density polyethylene pipes and fittings for pressure pipelines shall be in accordance with specifications issued WRC as Water Industry Specifications. The manufacturer shall be responsible for all testing and quality assurance procedures and be covered by a third party certificate scheme. Pipes exceeding 90mm nominal diameter shall not be supplied in coils.

(c) All HDPE pipes and fittings for thermal fusion jointing to form an individual pipelines or pipeline systems shall be supplied by one manufacturer unless the Engineer's approves otherwise.

2.15.6 Execution for the Other Pipes

All of the pipe work, pipe handling, laying, jointing, testing, backfilling and test certificates etc. shall be approved by the engineer.

2.15.7 Workmanship

(a) Manufacturer's Recommendations

Where installation procedures or any part thereof are required to be in accordance with the recommendations of the manufacturer of the material being installed, printed copies of such recommendations shall be submitted to the engineer prior to installation.

Installation of the item shall not be started until the recommendations are received. Failure to furnish such recommendations shall be one of the causes for rejection of the material.

(b) Installer's Qualifications and Acceptance Criteria for Drainage Work

a) All underground pipe drainage shall be executed by qualified and experienced personnel having valid license issued by the local authorities to execute the work which shall be approved by the engineer if applicable.

b) The Contractor shall procure all the permits and shall pay all fees and charges in connection with this work.

c) The whole drainage work shall comply with the regulations of the relevant local authorities and shall be completed to the satisfaction of relevant local authorities and the engineer if applicable.

d) Drainage pipes in general shall be free from fractures, large or deep cracks and surface roughness. The ends of pipes shall be normal to the wall and to the center line of the pipe. All pipes shall include bends and special fixtures of the same material as per drawing.

2.15.8 Inspection & Tolerances

(a) Inspection & Tolerances for all underground drainage work shall be in accordance with related specification.

(b) Inspection Before Installation

The following inspection shall be made before installation.

a) Assure that materials are of the type specified.

b) Check that pipe to be installed is free of interior bulges, damages, fractures, cracks or splits.

c) Check the grade of excavated trench bottom conforms to drawing after compaction.

(c) Inspection During Installation

a) Verify that pipe bedding & joints are constructed as specified.

b) In cast of underground cable laying, verify that the thickness of sand cushion & the distance between laid cables is maintained as per drawing. Also check that Megger testing of the cables is carried out.

c) Check for coverage of joints with concrete in case pipes are laid at a shallow depth below existing ground.

(d) Inspection after Installation

The following inspection shall be made after installation.

a) Assure the laid position of pipe to conform to drawings.

b) Check that joints are totally leak proof during hydro-testing.

c) Check compaction of backfill material.

2.16 ROAD WORKS: NO PAVEMENT

2.16.1 Earthworks

The earthworks for roads shall be in accordance with the requirements elsewhere in the Specification.

Where the dry density of the natural ground within 0.3 m depth of the formation level is below 90% of the maximum dry density as determined in DIN 18126 or equivalent standard, the sub-grade material shall be reworked and compacted to 90% of the maximum dry density.

Fill below 0.3 m depth under the formation level shall be compacted to 90% maximum dry density. Fill within 0.3 m depth of the formation level shall be compacted to 95% maximum dry density.

When compacting sub-grade sections, particular attention shall be paid to the requirement that the natural sub-grade or the fill shall be compacted with a slight outward slope to ensure good run-off of surface water.

Material excavated out of the road bed which is suitable for use in fill, shall be used for filling as far as this is practicable.

2.16.2 Murram

Murram shall be from an approved source quarried so as to exclude vegetable matter, loam, top soil or clay. The California Bearing Ratio of the murram, as determined for a sample compacted to maximum density (as defined under SRN 601) and allowed to soak in water for four days, shall not be less than 30%. This C.B.R. is a guide to quality only and the compaction in the work will be judged by density.

2.16.3 Murram Sub-Base

The murram sub-base will be constructed only in poor soil conditions where directed by the Engineer. The murram shall be from an approved source quarried so as to exclude vegetable matter, loam, topsoil or clay. The California Bearing Ratio (C.B.R.) of the murram, as determined for a sample compacted to maximum density as defined under B.S. 1377 and allowed to soak in water for four days, shall not be less than 30. This C.B.R. is a guide to quality only and the compaction in the work will be judged by density.

The murram sub-base shall be of the thickness as shown on drawings or stated in the Bill of Quantities. The sub-base shall be evenly spread and compacted using an 8-10 tonne roller for road construction and a 2-4 tonne roller for footpath construction. The Contractor will be required to maintain the selected material at its optimum moisture content to achieve maximum compaction. The roads and footpaths shall be finished to the grades and levels shown on the drawings.

2.16.4 Finish and Protection of Sub-grade

When the sub-grade has been compacted to the required degree, the surface shall have a formation parallel to the finished surface of the carriageway and to the correct levels and cross-section.

The finished surface of the sub-grade shall be approved by the Engineer before any sub-base material is placed. The sub-grade, once it has been finally compacted, shaped and approved, shall be protected and kept well drained.

Plant and materials shall not be stored or stockpiled on the formation. Contractor's traffic shall not be permitted to pass over the completed sub-grade unless otherwise approved by the Engineer. The Contractor shall, at his own expense, repair any soft spots or damage caused to the sub-grade.

2.16.5 Material and Construction of Sub-base

The granular material used in the sub-base shall comply with the requirements specified in DIN 4226. All material shall be placed, spread evenly and compacted, spreading shall be undertaken concurrently with placing. The material shall be spread in one or more layers so that after compaction the total thickness is as required. Compaction of the sub-base shall be to 98% of the maximum dry density in accordance with DIN 18126 or equivalent standard and shall be completed as soon as possible after the material has been spread. Where compacting plant is of insufficient capacity, the sub-base shall be laid in two or more layers. During the construction period the sub-base shall be maintained in such a condition that it will be drained at all times. The outflow shall be diverted away from the construction at all times. The outflow shall be diverted away from the construction in order to prevent erosion.

2.16.6 Requirements for Compaction

Vibratory compacting plant may be used if approved by the Engineer. The number of passes to be made will be determined having regard to the characteristics of the plant to be employed and the material to be used.

If necessary, test specimens shall be taken to determine the optimum method of compaction. The surface of any layer of material shall, on completion of compaction, be well closed, free from movement under compaction plant and free from compaction planes.

All loose, segregated or otherwise defective areas shall be made good to the thickness of the layer and recompacted.

2.16.7 Material and Construction of Base

The base shall comprise of one of the following:

(a) Selected gravel base

(b) Crushed stone

(c) Cement stabilised selected gravel base

The selected gravel or crushed stone base shall be minimum 150 mm or as required by the existing ground conditions. The base material shall be a well graded material complying with the following requirements:

(a) CBR value after 24 hours soaking shall not be less than 80 %

(b) Liquid limit and plasticity index shall not exceed respectively 25 % and 8 %

(c) The grading limits shall be:

BS sieve size	Percentage by mass passing
75 mm	100
37.5 mm	85-100
20 mm	60-100
10 mm	40-70
5 mm	25-45
600 micron	8-22
75 micron	0-10

The particle size shall be determined by the washing and sieving method of BS812: Part 103

The selected gravel or crushed stone base shall be compacted to 100% of maximum dry density.

Compaction shall take place by watering and rolling until there is no longer any visible movements of the compacted stone material and a stone of the base material when thrown under the roller shall become crushed. A finishing layer of sand shall be rolled in to fill the surface voids.

The cement stabilised selected gravel base shall be minimum 150 mm or as required by the existing ground conditions. The gravel material shall answer to the above specification and be stabilised with 6 - 8% of Portland cement. To obtain a uniform mixture of materials and water, the cement stabilised gravel base shall be manufactured in a pug mill, carried to the place of placement and compacted to 100% of maximum dry density. If the conditions on site allows it and the Engineer approves, the cement stabilised gravel base may be constructed on site by using rotary tillers and water bowsers to obtain a well mixed base.

The compaction requirement remains unchanged, i.e. 100% of maximum dry density.

The material shall be placed and spread evenly, spreading shall be undertaken concurrently with placing. Road base material shall preferably be spread in one layer using a paying machine or similar approved.

The material shall be spread so that after compaction the total thickness is as required. The Contractor shall organise the work in such a way that longitudinal joints against hardened material are avoided as far as possible. If this is not possible then before work proceeds against a longitudinal joint of hardened material, the edge compacted previously shall, if it has been exposed for more than an hour, be cut back vertically to produce a face equivalent to the specified thickness of the layer of properly compacted material.

Compaction of the road base to a minimum of 100% of the maximum dry density shall be completed as soon as possible after the material has been spread. Compaction equipment shall not bear directly on hardened or partially hardened material previously laid other than what is necessary for achieving the specified compaction of the joint. Special care shall be taken to obtain full compaction in the vicinity of both longitudinal and transverse joints and the Contractor shall use special small compactors in addition if necessary or instructed by the Engineer.

Any loose or poorly compacted material in the vicinity of construction joints shall be removed and replaced with fresh material. The surface of any layer of material shall on completion of compaction be well closed, free from movement under compaction plant and free from compaction planes, ridges, cracks or loose material. All loose, segregated or otherwise defective areas shall be made good to the fill thickness of the layer and recompacted. If this cannot be done within 2 hours of mixing, the making good shall comprise the material being broken out to the full thickness of the layer, removed and replaced with freshly mixed material compacted to Specification.

The base shall, immediately on completion or completion, be cured for a period of at least 7 days, unless otherwise approved by the Engineer. Curing shall be achieved either by covering with approved impermeable plastic sheeting adequately secured from being blown off the surface with joints overlapped at least 300 mm and set to prevent egress of moisture or in accordance with Clauses in the Specification dealing with concrete or by spraying with an approved curing compound.

Notwithstanding the above the Contractor shall construct the road base in accordance with the requirements and specification of the relevant Authority or Municipality. The Specification included herein shall be adopted only in the absence of any particular requirements from these authorities.

2.16.8 Temporary Construction Roads

(a) Definition and Purpose

A temporary road is a road that is designed and built along a temporary alignment, solely for use during construction. Temporary roads focus the ground disturbance of equipment and vehicles along a certain path, so that erosion and sediment movement can be planned and mitigated for in accordance with all applicable permits. Beyond focusing the disturbance, the location and design of temporary roads can actively aid in controlling erosion. Using other erosion control measures such as sloping, rolling dips, water bars, aggregate, level spreaders, water or chemicals for dust control, and culverts, in conjunction with temporary roads, may be appropriate and warranted.

(b) Appropriate Applications

- On all associated haul roads within a construction site, especially where fugitive dust needs to be controlled.
- Where traffic will be detoured onto unpaved areas.
- Where access to sensitive areas, such as wetlands or live streams, is required.
- Where access to a bridge sites is constructed ahead of excavation.

(c) Limitations

- Structures, such as water bars, road sloping, rolling dips and level spreaders are generally limited to low traffic volumes.
- Temporary constructed roads cannot encroach into jurisdictional wetlands without the appropriate permits.

(d) Construction Guidelines

- Adequately slope temporary roads for good drainage, and install all other structures such as water bars, culverts, and rolling dips, according to plans and specifications.
- Do not use road sloping on grades steeper than 5 percent unless other structures are also used. If road is steeper than 5 percent, use gravel surfacing to minimize erosion, and slope the road to the side that has a ditch.
- Make field adjustments, as necessary, to ensure proper performance.

(e) Temporary Construction Roads for SVTP

- Total length: 27km
- If each SC is separated from the existing road, decide the length of Construction Roads based on the distance from the Main Canal.
- SC2 does not reflect Construction Roads because it is well connected to the existing road network.
- In the case of MC3, a wide road width is required, so Construction Roads are reflected in all canal route.
- If additional Construction Roads are required other than those listed above, determine in consultation with the construction superviser.

2.17 ROAD WORKS: ASPHALT CONCRETE PAVEMENT

2.17.1 General

This construction specification covers general requirements for Asphalt Road work.

The Contractor shall be responsible for setting out the center lines of all roads and areas where required in relation to the given base line or lines and reference points as approved by engineer.

All radii at intersection and curves and all details shown on the drawings shall be strictly adhered to and all levels shall be set out from the Bench Marks on the site.

The Contractor shall check and verify the established Bench marks for location and elevation of grade, prior to commencement of setting out work.

The Contractor shall maintain all dimensional details such as width, shoulder, gradient, etc. in accordance with drawings.

2.17.2 Reference Standards

The applicable standards and testing shall conform to the recommendations of ASTM.

ASTM D2166 Standard Test Method for Unconfined Compressive Strength of Cohesive Soils.

ASTM D1556 Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.

ASTM D4186 Specification for Crushed Aggregate for Macadam Pavement.

ASTM D1195 Representative Static Plate Load Test of Soil & Flexible Pavement Component.

ASTM D1196 Non Repetitive Static Plate Load Test of Soil & Flexible Pavement Component.

ASTM D946 Penetration-Graded Asphalt Cement for Use in Pavement Construction.

2.17.3 Submissions by the Contractor

- The Contractor shall submit test-certificates for all materials supplied by the contractor as and when called for by engineer. The Contractor shall also give the details such as source of supply, gradation standards, size of aggregates, details of mix etc.
- For Bituminous or Asphalt road pavements, the Contractor shall submit in advance Job Mix Formula stating all the details such as Grade of Bitumen, flash point, penetration, sieve analysis of aggregates, final temperature of hot mix, curves for gradation of aggregates, final mix proportion, minimum content of asphalt or bitumen per cubic meter of hot mix, etc. This shall be submitted to engineer at least 30 days prior to commencement of work to enable engineer to study the same and for his approval and comments. Approval of the Job Mix Formula by engineer shall not relieve the contractor of his contractual obligations and quality

control responsibilities.

2.17.4 Materials

The mixed materials shall be transported from mixing plant to the site of work in clean vehicles and shall be covered with tarpaulins while transportation to prevent loss of heat from the asphalt hot mix (for example) and to minimize contamination due to dust or rains and for general traffic safety purposes while the material is being transported in open trucks or dumpers which have uncovered top side.

Every precaution shall be taken to prevent segregation of mixed material while transporting, loading and unloading.

(a) Materials for Asphalt Concrete Road and Paving

a) Coarse Aggregates for Asphalt Wearing Course Crusher run hard rock shall be with sharp edges. The rock shall be granite rock having uniform color free from fissures and salts to the maximum extent. The crushed rock shall be hard, dense durable, clean and the sizes shall conform in accordance with required gradation.
Gravel if specified shall be river bed gravel and shall consist of natural or artificial mixture of hard pebbles.

b) Fine Aggregates for Asphalt Wearing Course
Fine Aggregates shall be clean, and shall be obtained from either a river bed, pit or sand quarry or shall be fine particles of crushed stone. The size of particle shall not exceed 6 mm.
The fine aggregates shall be sharp edged and shall be free from organic impurities, decomposed material, soil, clay, loam, and other foreign matter and shall generally conform to ASTM D1073. Sea sand shall not be used.

c) Grading of Aggregates
Maximum size of aggregate shall be 13 mm or 20 mm.

d) Bitumen
Bitumen shall be road bitumen conforming to recommendations of ASTM D946 having a bitumen content of not less than 90%. Bitumen having penetration greater than 85/100 shall be used unless otherwise specialty required.

e) Bitumen Emulsion
Bitumen emulsion shall have bitumen content of not less than 60%.

(b) Mechanically Stabilized Crushed Stone and Gravel
Crushed stone and gravel shall consist of a natural or artificial mixture of hard, durable particles of uniform quality. The material shall be free from soft or decomposed particles and excess clay, and shall be uniformly graded so that it can be compacted into hard, dense mass.

(c) Soil for Embankment
Soil for embankment filling shall be generally granular and shall be free from organic decomposed material, humus, clay etc. Heavy clayey soils shall not be used.

(d) Manholes and Street Gullies
Pre-cast concrete chamber rings for manholes and inspection chambers and street gullies shall comply with the requirements of ASTM C 139 'Standard Specification for Concrete Masonry Units for Construction of Catch Basins and Manholes'. The concrete shall be made with

ordinary Portland cement unless specified otherwise. The unit shall be supplied to the typical details shown on the drawings and to the required dimensions. Cast iron covers and gully gratings and frame shall be of the grades shown on the drawings.

2.17.5 Execution

(a) Excavation/Grading/Leveling

a) In accordance with the cross sectional profile of the road, there shall be cutting and filling involved for road work.

b) Stripping and Spreading of Topsoil

1) All topsoil shall be stripped from areas to be paved, excavated or filled and from other areas as shown in the drawings.
All organic impurities shall be removed while carrying out stripping of the area for the road or pavement.

2) The depth of the topsoil shall be in accordance with drawings or as instructed by engineer.

c) Excavation

1) Excavation shall conform to limits indicated on the Drawings or specified herein.

2) Excavation shall not be made below grade except where rock or stone masonry is encountered or removal of unstable material as directed by the Engineer.

3) Material removed below grade shall be replaced with approved material thoroughly compacted or as otherwise directed by the Engineer.
Where excavated material is required for the construction of embankments, for road, etc. and the material encountered in excavation consists of earth, soft rock, and hard rock, the contractor shall construct the bottom of the fills with hard rock, following this with soft rock and finally the earthfill.
Care shall be taken throughout to provide well compacted and void free embankment.
The work shall also include stockpiling and rehandling which shall be carried out by the contractor at no extra cost to the Engineer.

d) Borrow Materials

1) Construction method of Embankment shall be done same as in construction specification : “2.2. Earth Works”.

2) Where additional material is required to complete the embankment or fill, the Contractor shall provide it. This borrow material shall be inorganic material approved by the Engineer.

3) The Contractor shall give engineer at least 5 days' notice to permit cross-sectioning before removing borrow material from any approved borrow pit.

e) Filling

1) The soil for filling shall be approved by engineer and prior to being used, shall be given a compaction test to determine its suitability.

2) Fills shall not be started until the area has been inspected and approved by the Engineer.

3) Embankment and fill material shall be free from frost, stumps, trees, roots, sod or muck.

4) Compaction shall be carried out by Vibration roller and macadam roller when required depth, width and strength is obtained.

f) Subgrade

1) Sloped surfaces steeper than 4:1 shall be scarified or stepped and compacted to provide bond with new material. When existing roadways are to be covered with less than 300 mm of fill, the surface shall be scarified and recompacted to the same density as specified for fills.

2) Before starting with clearing and refilling the roadway and shoulders or temporary road shall be drained of all surface water and ground water over the whole width of the road. Dewatering shall be carried out at the Contractor's own expenses.

3) Sub-grade shall be compacted with vibratory rollers and plane steel rollers weighing not less than 10 tons including watering wherever necessary to attain a compaction density of not less than 95% of Max, Dry Density as per ASTM D1556 or D1557. Clay soils and heavy clay sub-grade shall be compacted with sheep's foot rollers. Watering shall be carried out by the contractor. Final compacted surface shall be slightly trimmed by a grader to the required camber and slope as per drawing and the top level of finished sub-grade shall conform to drawings. Compacted sub-grade shall not be disturbed while trimming with grader blade. Finish tolerance of sub-grade : ±25 mm at any point

g) Base Course

The base course shall consist of the following

1) Crusher run stones which shall be well compacted with intermediate filler material to fill the interstices until there is no movement of the stones under the roller and also to the satisfaction of the Engineer.

2) Mechanically stabilized Gravel and Crushed Stone Base Course :

This base course shall not be constructed on a wet sub-grade or sub-base. The material shall be deposited and spread in lanes in a uniform layer without segregation of size to such loose depth that when compacted, making due allowance for any admixture that is to be blended, the layer will have the required thickness. In the event of any segregation, the material shall be mixed with harrows, blades, rotary tillers etc. to obtain uniform mixture.

Mixing shall continue until the mixture is uniform throughout. When the mixing and blending have been completed, the mixture shall be spread to a uniform depth sufficient to give the required thickness of layer when compacted. Water shall be added in requisite amount while mixing to maintain uniform moisture content of the mix.

The surface shall then be given one pass with roller, after which the surface shall be checked with straight edge and the surface irregularities shall be corrected.

Each layer shall be compacted for full width and depth by rolling with a tire roller or a three wheel power roller weighing not less than 10 tons. Alternate blading and rolling shall be required to provide a smooth, even, and uniformly compacted course true to cross section and grade.

Final Cross section shall be checked for camber by a template to correct all the undulations.

The mix moisture content shall be controlled by draining and aeration when too wet or by adding water when too dry. Finish Tolerance : ±15mm at any point.

3) Water Bound Macadam Base Course

This base course shall not be constructed during wet season overwet sub-base or sub-grade. This base course shall be constructed over already prepared sub-grade or sub-

base course. This base course shall be constructed in layers not exceeding 100 mm when compacted. Sufficient coarse aggregates shall be uniformly spread to give the required thickness when compacted with minimum 10 Ton roller.
The voids shall be filled with screenings and the macadam shall be sprinkled with water being followed by the roller. This sprinkling, filling voids with finer materials such as screenings and rolling shall continue until voids are completely filled and the coarse stone firmly set and bonded throughout the depth of the layer.
Should the sub-grade or sub-base at any time become soft or churned up with base course material, the contractor shall, without additional compensation, remove the mixture from the affected portion, re-shape and compact the sub-grade or sub-base and replace the removed section. Coarse aggregates shall not be spread more than 2,000 m² and never more than 150° linear meters in advance of rolling and spreading screenings and brooming.
Tolerance : The surface shall be true to the established grade surface, and shall not vary more than 6 mm in 3 m length from the true profile and cross section.

4) Bitumen Stabilized Base Course
The compacted sub-base top shall be covered with prime coat. Prime coat shall consist of Medium Curing or Rapid curing Cut Back asphalt applied at 1.5 liters per 1 m² at 45°C temperature.
The sub-base surface shall be totally dry and free from moisture and dust before applying prime coat by mechanical spray. Sand and gravel and hot bitumen shall be premixed in hot mix plant and this mix shall be transported to the site and spread to the site and spread to the desired thickness and width so as to get a compacted thickness as shown in the drawing. The mix temperature at the time of placing shall not be less than 110°C. The mix shall be placed by a mechanical spreader. All cold construction joints shall be chipped before new mix spreading starts.
The hot mix shall be compacted when the temperature of mix is between 90°C to 70°C. Initially with water sprayed tire rollers and afterwards with 10T steel road roller.
Thickness of layer shall not exceed 120 mm when compacted.
Rolling shall be carefully done to avoid forming surface cracks due to flow of hot mix when it is very hot whereby rolling at that temperature may cause a slight flow of the mix.
Rolling shall not be carried out when the temperature of the mix is below 70°C otherwise cold mix may crack.
After final rolling, the surface shall be checked for thru section, camber and gradient.

Corrective measures shall be taken after checking the camber of the road, grade etc.

Tolerance : permissible variation : ±10 mm per 10 meter length.

2.17.6 Asphalt Concrete Work

(a) The Contractor shall place the Asphalt concrete in the locations and in the thickness indicated on the drawings. Compaction by rolling shall be performed in three stages.
Primary rolling, Secondary rolling and Finish rolling.
Other description shall be similar to Bitumen Stabilized base course except for the following.

a) Material used for asphalt concrete shall consist of coarse, and fine aggregates of specified sizes and mix proportions as specified and asphalt.

b) Only dry aggregates shall be mixed hot in the hot mix plant using specified grade of bitumen asphalt depending upon the grade of asphalt to be used for the work.

(b) Each layer of the sub-base and base course shall be compacted to at least 95% of maximum dry density as determined by the test conforming to ASTM D1557.
Surface/dimensional tolerance : ±15 mm for every 6 m length.

2.17.7 Road Machinery & Equipment

The Contractor shall utilize and employ machinery for carrying out road work which shall be in good turning condition.

All the costs of fuel, oils lubricants, water, maintenance, operators, spares and repairs, etc. shall be borne by the Contractor.

Major equipment for various types of work shall meet the basic requirements of specifications and surface tolerances as specified earlier.

2.17.8 Inspection and Test

(a) Inspection
All inspection shall be carried out in accordance with the Inspection and Testing Procedures.

a) Shoulders shall be provided for the road in accordance with the drawings which shall be treated as integral part of the road work.

b) Road camber shall be checked with wooden or metal templates for true camber.

c) All subsequent layers such as sub-grade, sub-base, base course etc. shall be protected from damage due to rains or passing vehicles until the next layer is constructed over the earlier layer.

d) Any repairs, patch work, removal due to failure of field test results etc. shall be carried out by the Contractor as directed by the engineer at no extra compensation to the contractor.

e) The Elevation for curvatures shall be provided as per drawings or as directed by the Engineer.

(b) Workmanship

For all the items listed below, the contractor shall submit a request for inspection to the Engineer at least three days prior to carrying out the work.

a) General Work

Item	Description	Frequency	Allowable Limit
Level	Sub-grade	Every 500 m^2	±3 cm
	Surface of Sub-base and Wearing Coarse	- ditto -	±3 cm
Width	Each course	- ditto -	±3 cm
Thickness	Asphalt Wearing Course	- ditto -	more than specified thickness

	Other Course	- ditto -	- ditto -

b) Paving Work

Item	Description	Frequency	Allowable Limit
Level	Gravel Spreading	Every 500 m2	±2 cm
Thickness	Gravel Spreading	- ditto -	±2 cm

(c) Tests

a) The Contractor shall execute and shall bear all the costs and expenses for all tests.

b) The Contractor shall obtain and submit material test certificates stating the guarantee of quality of factory supplied materials conforming to specified standards of equivalent. Materials such as bitumen shall be certified by the manufacturer/supplier as to the grade of bitumen, and its quality conforming to specified standards.

c) The following quality control tests shall be carried out by the Contractor.
The results from these tests shall be submitted to the Engineer as soon as possible after carrying out these tests.
Testing laboratory shall be an authorized institute or government body recognized as the standard testing laboratory of repute in the country.
All test charges shall be borne by the Contractor.

Road	Test	Frequency	Allowable Limit
Subgrade	Field Density Test (rd)	Every 100 m	Not less than 95% of rd max
Base Course	Plate Bearing Test (K30)	Every 500 m	Not less than 20 Kg/c㎥
Asphalt Wearing Course	Temperature	Every Truck or lorry	
	Grading of aggregate	Once a month at Point of production	2.5mm sieve : ±15% of the value specified in JOB MIX FORMULA
	Asphalt Content	As per engineer's instructions	±1.2% of the value specified in JOB MIX FORMULA
	Density	Every 500 m	Not less than 95% of the value specified in JOB MIX FORMULA

Marshall Density, Marshall Flow tests for asphalt concrete and specific gravity shall be tested for every 2000 m² of road carpet area.
The Compaction tests for asphalt concrete shall be carried out at the rate of one test per 1000 m² at the place designated by the Engineer by taking 150 mm diameter core samples at site.

2.18 GABIONS (WALL TYPE, FOR MATTRESS)

2.18.1 Materials

(a) General Materials

- Gabions are made into box shapes in various sizes of iron nets in duplicated twists of pentagonal or hexagonal mesh types using iron mesh rods with strong corrosiveness. They adopt the production where solid stones may be filled in a box.
- An iron wire thicker than the iron wire in the main structure shall be used for the circumferential iron wire in a gabion.
- An iron net shall be twisted and connected in a duplicated manner as well as in a pentagonal or hexagonal shape, so that the disconnection in any area may no cause the entire collapse with the flexibility to endure any form of settlement. The mesh size shall be 8×8~10 cm.
- The internal partitions shall divide the gabion box inside into the same size and the length of each section shall be within 1.5 times as large as the width.
- The connecting iron wire shall be used for assembling and connecting gabions and made from the same material consisting of gabions.
- The filling material shall be solid, dense and durable stone and the large or small components shall be distributed and maintained evenly, which is good with durability as well as proper strength in the rounded or cornered shape.
- Stone shall not include minerals to be discolored or deformed by weathering. It shall not be worried about breaking due to weathering or freezing. The assembly ratio between filling materials shall be good after placement. The compression strength under BS shall be 50 MPa or more and absorption shall be 5% or less. Its specific gravity shall be about 2.5 or more. Regardless of stone color, it may be used if the testing regulations are met, but shale stones or mudstones may not be used.

(b) Quality control and test

- Materials for gabions shall follow testing regulations under the relevant standards as an iron wire with anti-corrosiveness in zinc plated iron wire class 5 or equivalent or better. The sampling shall be taken in the presence of the construction supervisor before use after delivery to the site to take the control testing.
- Gabions shall be able to prevent the loosening due to the mutual connection of mesh in hexagonal shape from the winding and twisting of iron wire net section three and half times as many, as well as in pentagonal shape from the winding and twisting of iron wire net section two and half times as many by the horizontally reinforcing iron wire together with net section iron wire as mentioned before. Gabions shall be made under drawings, as well as division in the unit of 1 m with the woven iron net in hexagonal mesh with the steel wire. General specifications of gabions are shown below.

Division	Net section (cm)	Iron wire		Size (m) (B × H × L)	Remarks
		Area	Diameter (mm)		

Mattress type Wall type	8 × 8~10	Circumferential iron wire	3.4	2.0 × 0.48~0.50 × 6.0 2.0 × 0.28~0.30 × 6.0 1.0 × 1.0 × 1.0 1.0 × 1.0 × 2.0 1.0 × 0.5 × 1.5 1.0 × 1.0 × 1.5	Customized production in case of change in dimension
		Horizontally reinforcing iron wire	3.4		
		Net section iron wire	2.7		
		Connection iron wire	2.2		

- The corner, partition and edge of gabions shall be made into solid circumference to sufficiently maintain the iron mesh structure as well as to prevent the loosening of iron mesh structure.
  1) The iron wire used for edge shall be thicker than that used for mesh.
  2) Both the gabion end panel and partition shall become circumference perpendicularly to the top line. The end panel shall be connected by the dual twisted end finish of the mechanical iron mesh at the circumference of the gabion bottom panel.
  3) The partition shall be connected to the floor by the connection in spiral shape passing through each net frame between the mesh gap and partition panel.
- The seaming iron wire shall be used for the strong connection of gabions, and this iron wire shall have the same characteristics as those of iron wires consisting of gabions, and the thickness of iron wire shall be 2.2 m.
- Tolerance in dimension for every gabion shall be within 5% of the required size and within 5% of the length.
- River aggregates (solid boulders) and rocky mountain aggregates (blasted rocks or rubbles) may be used for filling material.
- The most appropriate size of aggregates as the filling material shall be larger than the net section and smaller than 1/2 of the gabion height. The size shall be around 80 ~ 150 mm if the gabion height is 0.3 m wall, and around 100~250 mm if the height is 0.5 m wall, and 150~300 mm if the gabion height is 1.0 m wall.
- 85% or more of gross stone weight in wall type gabion shall abide by provisions in General and (H) in Quality Control and Test, and stones to fill small spaces shall not exceed 15%.

- Unit Weight per Stone

Type	Unit Weight (kg/㎥)	Remarks
Granite	2,600 ~ 2,700	
Basalt	2,700 ~ 3,200	
Andesite	2,300 ~ 2,700	
Sandstone	2,400 ~ 2,790	

2.18.2 Construction

(a) Filter mattress shall be placed on the already completed levee slope and the assembled empty mattress gabions shall be installed within the working range of work equipment (backhoe, etc.)

(b) Drooping shall be prevented due to the input of filling materials by driving the fixing piles on the foundation with iron rods to prevent the installed gabions from bending or unbalancing to one side.

(c) For the installation of binding iron wire to connect the floor mesh and cover mesh to tie up the top cover before the input of filling materials, the connecting iron wire is pulled up by twisting iron wires twice or more on the floor mesh; the installation of the cover mesh is done after the filling stones are filled; and both the floor mesh and cover mesh shall be installed in a more uniform way by twisting and binding the already installed connecting and binding iron wire twice or more in a strong manner to the net section mesh in the cover.

(d) As mattress type of gabions are implemented on the mounding section of a levee in most cases, the partial settlement may occur due to the weight of filling materials despite compaction on the mounding. Accordingly, more filling materials shall be filled than the actual height, while the gap is minimized.

(e) When the foundation is thought to be stabilized after the placement of filling materials, the surface leveling shall be done for the filling materials. And then, the cover shall be placed, where the connection shall be strong for the close tightness between the filling materials and the cover. As the flow of runoff exist on the revetment surface all the time, the cutting shall be shortened as much as possible to prevent any floating objects from being stuck in the connecting iron wire and the cut area shall be bent and inserted into the net.

(f) The gap of the binding section shall be around 20 cm when the partition and cover of gabions are assembled. The material for the binding iron wire shall be the same as that of gabions and its thickness shall be 2.2 mm. The knob of iron wire shall be made twice or more and the connection shall be done in a uniform way for all.

(g) If the foundation is fragile when the wall type gabions are constructed, the ground improvement shall be done or support concrete shall be placed to support the weight of gabions.

(h) If the wall type gabions are constructed, 1/3 out of 1m height of gabions shall be filled, the intermediate iron wire shall be connected to adjust the front perpendicularly, and then, stones are filled and the support iron wire is connected again in about 2/3, and stones are filled up to the top.

(i) The covering of good sand and earth shall be carried out in about 20 cm of the installed area in consideration of the gap ratio of filling materials for the quick rooting and maximizing of vegetation survival after the construction of mattress type gabions, and 15 cm of soil depth for the minimum survival of vegetation shall be secured.

2.19 FENCE AND CHAIN LINK

2.19.1 General

The work under this spec. shall consist of furnishing all labor, tools, materials, Constructional plant, and other items necessary for the complete installation of chain-link fabric fence including gates at the locations indicated on the drawings and as specified herein.

2.19.2 Reference Standards

Reference Standards for fence and chain link shall follow the Design Standards and detail codes described in sub-section 1.1.3. All work in this section shall be carried out in accordance with locally applicable standards and codes of practice for material and workmanship or applicable codes and standards. Related construction specifications shall comply with the requirements indicated in the construction specifications described in sub-sections for "2.2. Earth Works" and "2.3. Concrete Works".

2.19.3 Materials

(a) General

Materials shall conform to the respective specifications and other requirements specified herein.

(b) Chain-Link Fabric

Chain-link fabric shall be zinc-coated steel wire fabric (galvanized after weaving) that conforms to the requirements of ASTM A-392, or equal. Chain link fabric shall have Class 1 zinc coating-366 grams of zinc per square meter minimum of uncoated wire surface. Chain-link fabric shall be 3.76 mm steel wire woven in a 50 mm mesh.

(c) Posts

Posts shall be of the material, size, and length indicated on the drawings. All steel pipe posts shall have tops provided with covering to exclude moisture. All concrete posts shall be precast.

a) Steel pipe line (or intermediate) post shall be 50 mm in diameter

b) Steel pipe terminal (end, corner, and pull) post shall be 100 mm in diameter.

c) Gate Post shall be steel pipe 150mm in diameter

d) Concrete post shall be precast, reinforced concrete post of the dimension and length indicated. Cement, coarse and fine aggregates, forms, admixtures, and water shall be in accordance with the applicable requirements specified in the Specification entitled in section 2.5 for Concrete Works. Steel reinforcement shall be in accordance with the applicable requirements specified in section 2.5 for Concrete Works.

(d) Top Rail and Bottom Rail

Top rail and bottom rail shall be fabricated from steel pipe 30 mm in diameter.

(e) Bracing

Bracings for terminal (end, corner, pull, and gate) posts shall be fabricated from steel pipe 30 mm in diameter.

(f) Barbed Wire

Barbed wire shall be zinc-coated (galvanized). Barbed wire shall consist of three (3) strands of 2.50 mm wire with 2.00 mm wire four-point barbs spaced approximately 12.7 cm apart. Steel wires shall have a minimum coating of 244 grams of zinc per square meter of surface area on 3.03 mm wire.

(g) Tie Wire

Tie wire shall be zinc-coated (galvanized) steel tie wire conforming to the requirements of ASTM A 112, or equal. The galvanized tie wire shall have a nominal diameter of 2.66 mm (12 gage) and a minimum zinc coating of 244 grams of zinc per square meter (0.80 ounces of zinc per square foot) of uncoated wire.

(h) Miscellaneous Metal Items

Miscellaneous metal items such as tension rods, turnbuckles, stretcher bars, clamps, ends of top rails and bottom rails, bolts and nuts, hook bolts, mounting clips, and stiffener plates shall be as indicated on the drawings.

(i) Gates

Gates shall be swing type as indicated on the drawings, complete with latches, stops, keepers, hinges, and provided with three (3) strands of barbed wire above the fabric.

a) Gate frames shall be constructed of steel pipes 50 mm in diameter welded at all corners. Tension rods with turnbuckles shall be provided to prevent sag or twist. The end members of the gate frame shall be extended above the top horizontal member to accommodate three (3) strands of barbed wire and tension rod. Gate frames shall be zinc coated (galvanized) after fabrication.

b) Fabric shall be the same type as used in the fence construction. The fabric shall be attached securely to the gate frame by tie wires at the top and bottom frame at intervals not exceeding 40 mm and at the side frames by stretcher bars with hook bolts.

c) Hinges shall be of adequate strength for the gate and with large bearing surfaces for clamping in position. The hinges shall not twist or turn under the action of the gate. The gates shall be capable of being opened and closed easily by one person.

d) Latches, stops, and keepers shall be provided for all gates. Latches shall have a plunger bar arranged to engage the center stop, except that for single gates less than three (3) meters wide a forked latch may be provided. Latches shall be arranged for locking. Center stops shall consist of a device arranged to set in the concrete and to engage the plunger bar of the latch of double gates. No stop is required for single gates. Keepers shall consist of mechanical device for securing the free end of the gate when in the full swing position.

(j) Zinc Coating

All steel and iron parts of the fence shall be zinc-coated after fabrication in accordance with the requirements of ASTM A123 of ASTM A 153, or equal, unless otherwise specified.

The minimum weight of zinc coating per square meter of actual area shall be 366 grams.

(k) Compressive Strength of Concrete

Concrete for footing of concrete posts and steel pipe gate post shall have 14 MPa compressive strength after 28 days. Cement, coarse and fine aggregates, admixtures, and water shall be in accordance with the applicable requirements specified in the Specification entitled "2.3. Concrete Works".

2.19.4 Installation

(a) General

The chain link fabric fence shall be constructed using new materials, in accordance with the details on the Drawings and as specified herein. All work shall be performed in a workmanlike manner satisfactory to the Engineer and the Engineer. The finished fence shall be plumb, taut, true to line and grade, and complete in every detail.

(b) Excavation

Excavation for concrete-embedded items shall be of the dimensions indicated. Post holes shall be cleared of loose material. Waste material shall be spread where directed.

(c) Post Spacing

Posts shall be evenly spaced a maximum of three (3) meters on centers unless otherwise directed. Straight runs between braced posts shall not exceed 30 meters.

(d) Post Setting

Posts shall be set plumb and in alignment. Posts shall be set in pipe sleeves previously installed on the concrete deck and in concrete bases of dimensions indicated elsewhere. When set in pipe sleeves, the space between the steel pipe post and the pipe sleeve shall be filled with molten lead or sulfur compound. When set in concrete base, the concrete shall be thoroughly worked and compacted into the hole so as to be free of voids and finished in a dome. Concrete shall be cured a minimum of 72 hours before any further work is done on the posts.

(e) Top Rails and Bottom Rails

Top rails and bottom rails shall be securely attached to the post by means of malleable iron clamps and bolts before installing the chain-link fabric. Top and bottom rails shall have one rail end fitting each as shown on the drawings.

(f) Chain-Link Fabric

Chain-link fabric shall be pulled taut and secured to the line post, and the top and bottom rails, by means of two (2) strands of 2.66 mm galvanized steel tie wire at intervals of not more than 60 cm on centers. Fabric shall be secured to terminal (end, corner, and/or pull) post and gate post with stretcher bars, clamps, clips, and hook bolts at intervals of not more than 60 cm on centers.

(g) Barbed Wire

Barbed wire shall be installed on supporting arms above the fence posts. The end members of gate frames shall be extended sufficiently above the top member to carry strands of barbed wire in horizontal alignment with barbed wire strands on the fence. Each strand shall be pulled taut and securely fastened to each supporting arm and extended member. The method of securing wires shall be positive and complete.

(h) Gate

Gates shall be hung on gate fittings attached to the gate post as shown on the drawings. The socket for the plunger bar or latch rod shall be set in concrete so that the latch rod will fit perfectly in the socket when the gate is in a closed position. Gates shall be erected to swing in the direction indicated. All hardware shall be secured and properly adjusted for easy operation. Hinges and diagonal bracings in the gates shall be adjusted so that the gates will hang in a level position.

2.20 PAINTING WORKS

2.20.1 General

The work covered by this section includes the requirements for material surface preparation, painting and protection requirements for civil and building works and for such steelwork as is not covered elsewhere in the Specification.

Where not otherwise required by the Specification, or by paint or coating manufacturer's recommendations approved by the Engineer.

The term "paint", as used herein, includes emulsions, enamels, paints, stains, varnishes, sealers, cement-emulsion filter, and other coatings, whether used as prime, intermediate, or finish coats, Surface cleaning and painting not specified in other sections shall be as specified herein.

2.20.2 Reference Standards

Reference Standards are referred to in the follows

ASTM B117	Standard Practice for Operating Salt Spray (Fog) Apparatus
ASTM ANS/ISO 1522	Paints and Varnishes - Pendulum Damping Test Approved as an American National Standard by ASTM International
ASTM A 120	Specification for Pipe, Steel, Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless, for Ordinary Uses
ASTM A 153	Specification for Zinc Coating (Hot-Dip) on lron and Steel Hardware
ASTM A 90	Test Method for Weight of Coating on Zinc-Coated (Galvanized) iron or Steel Articles.
ASTM C 884/C 884M	Standard Test Method for Thermal Compatibility Between Concrete and an Epoxy-Resin Overlay
ASTM D 1006	Standard Practice for Conducting Exterior Exposure Tests of Paints on Wood
ASTM D 1014	Standard Practice for Conducting Exterior Exposure Tests of Paints and Coatings on Metal Substrates
ASTM D 1652	Standard Test Method for Epoxy Content of Epoxy Resins
ASTM D 3168	Standard Practice for Qualitative Identification of Polymers in

	Emulsion Paints
ASTM D 4142	Standard Guide for Testing Epoxy Resins

2.20.3 Submissions by the Contractor

Samples of each different painting material, properly tagged and marked for identification, shall be submitted to the Engineer for approval.

2.20.4 Materials

Materials shall conform to the respective publications and other requirements specified herein and as shown, and shall be the approved products of manufacturers regularly engaged in the manufacture of such products.

Materials shall be delivered, stored, handled, and installed in a manner to protect them from all damage during the entire construction period. All damaged material shall be replaced by the Contractor at his own expense.

(a) Materials

Paints shall be in sealed containers that plainly show the designated name, formula or specification number, batch number, color, quantity involved, date of manufacture, manufacturer's formulation number, manufacturer's directions, and name of manufacturer, all of which shall be plainly legible at the time of use. Paint containers shall not exceed 20 liters capacity with the exception of containers for emulsion, spraying paints, bituminous paints, stone, cement and road-marking paints which may be of larger capacity. Materials shall conform to the specifications shown in the painting schedule herein and to the requirements herein specified.

(b) Acrylic emulsion paint shall be used for the exterior for concrete masonry unit, cement plaster, and asbestos cement board surfaces. Cement-emulsion filler coat shall be either acrylic base cement-emulsion filler or polyvinyl acetate base cement-emulsion filler. When used in an exterior system, the polyvinyl acetate base cement-emulsion filler coat shall be used only with a polyvinyl acetate exterior emulsion finish paint, and the acrylic base cement emulsion filler coat shall be used with an acrylic exterior emulsion finish paint.

(c) Exterior oil paint shall be ready mixed white and light tints (alkyd resin type).

(d) Zinc coated shall conform to following standards.

ASTM A 120	Specification for Pipe, Steel, Black and Hot-Dipped Zinc-Coated (Galvanized) Welded and Seamless, for Ordinary Uses
ASTM A 121	Specification for Zinc-Coated (Galvanized) Steel Barbed Wire
ASTM A 123	Specification for Zinc (Hot-Dip Galvanized) coatings on lron and Steel Products
ASTM A 153	Specification for Zinc Coating (Hot-Dip) on lron and Steel Hardware
ASTM A 392	Specification for Zinc-Coated Steel Chain Link Fence Fabric

(e) Paints and varnish shall conform to ASTM ANS/ISO 1522 “Paints and Varnishes - Pendulum Damping Test Approved as an American National Standard by ASTM

International", or equal.

(f) Stain shall be commercially available oil type for interior wood surfaces, with shades as selected and approved by the Engineer.

2.20.5 Cleaning, Preparation and Pretreatment

(a) General

All hardware, accessories, machined surfaces, plates, lighting fixtures electrical, telephone, signal and special purpose outlets, electrical receptacles, switches, and similar items in place and not intended to be painted shall be removed, masked, or otherwise protected, prior to surface preparation and painting. Following completion of painting of each space, removed items shall be reinstalled. Such removal and reinstalling shall be done by workmen skilled in the trades involved. Surfaces of all materials to be painted shall be clean and free from loose particles, dirt, and foreign matter before applying the paint or surface treatment. Oil, grease, and other contaminants harmful to paint adhesion shall be removed with clean cloths and an appropriate cleaning solvent prior to mechanical cleaning except when sandblasting is employed. Cleaning and painting shall be so program that dust and other contaminants from the cleaning process will not fall on wet, newly-painted surfaces. Painting shall not proceed until all imperfections, cracks, and holes in surfaces to be painted are repaired in an approved manner. Any painted surface marred or otherwise damaged shall be cleaned, repaired, and repainted.

(b) Concrete, exterior cement plaster and concrete-masonry unit surfaces to be painted shall be prepared by removing efflorescence, chalk, dust, dirt, grease, oil, asphalt, tar, excessive mortar, and mortar droppings, and by roughening to remove glaze. Surface deposit of free iron shall be removed prior to painting. Immediately before coating with cement-emulsion filler, concrete-masonry-unit surfaces to be painted shall be uniformly and thoroughly dampened, with no free surface water visible, by several applications of potable water with a fog spray, allowing time between to spraying for the water to be absorbed.

(c) Wood Surface (Wood and Plywood)

a) General
Wood surfaces to be painted shall be cleaned of dirt, oil, and other foreign substances with mineral spirits. Finished surfaces exposed to view shall be made smooth by sanding. Areas where resin has exuded from the wood shall be scraped clean and sanded prior to application of knot sealer. Recesses, cracks, joints, crevices, and nail holes in the wood shall be filled with glazing putty or plastic wood compound and sanded flush with the wood. Knots shall be surface scraped and thoroughly cleaned, and shall be given a thin coat of know sealer before application of the priming coat. Painting shall proceed only when the moisture content of the wood does not exceed 12 percent.

b) Interior wood surfaces to receive stained or natural finish shall be stained to the approved shade and lightly sanded. Open-grain wood shall be given the same treatment and, in addition, shall be given a coat of paste wood filler, not less than eight(8) hours after the application of the stain. The filler shall be thinned to brushing consistency with mineral spirits, using a stiffer mixture for woods with pores of moderate size. The mixture shall be brushed well into the wood and allowed to stand a few minutes for much of the thinner to evaporate and for the coating to turn dull. However, before the mixture has time to set the excess filler shall be wiped off with rags, burlap, or other suitable material. The first wiping shall be in a direction at right angles to the grain of the wood and shall include a padding or pounding action to pack filler into the wood pores. Final strokes shall be done in the direction of the wood grain. The surface shall then be sanded smooth. Each varnish coat shall be allowed to stand at least overnight to dry and lightly sanded prior to application of subsequent coat.

(d) Ferrous surfaces that have not been shop-coated shall be solvent-cleaned to remove oil and grease. Surfaces that contain loose rust, loose mill scale, and other foreign substances shall be mechanically cleaned by power wire brushing or sandblasting. Minor amounts of residual rust that cannot be removed except by thorough blast-cleaning, and tight mill scale that cannot be removed by applying a sharp knife to any edge, will be allowed to remain. After cleaning, one coat of ferrous-metal primer shall be applied to ferrous surfaces to receive paint.

Shop coated ferrous surfaces shall be stored out of contact with the ground in a manner and location to minimize the formation of water-holding packets, soiling contamination, and deterioration of the paint film. Such metal work shall be protected from corrosion before and after installation by treating corroded areas immediately upon detection. Abraded or corroded spots on shop-coated surfaces shall be wire-brushed and touched up with material similar to the shop coat.

(e) Nonferrous Metal

All nonferrous metal surfaces, such as aluminum alloy (except anodized), copper, zinc-copper-alloy, and zinc-coated surfaces, shall be solvent-cleaned as necessary to remove all oil, grease or other foreign substances. Where galvanized metal is specified, surfaces shall be prepared and finished the same as for zinc-coated metal. All zinc-coated metal shall be protected from corrosion before and after installation by treating cut, scarred, corroded, or abraded spots immediately upon detection; such spots shall be thoroughly wire-brushed, cleaned, and smoothed, and primed with zinc dust-zinc oxide.

(f) Plaster

Surfaces shall be dry, clean, and free from grit, loose plaster, and surface irregularities before paint is applied. When paint is applied, the instrument-measured moisture shall not exceed eight (8) percent.

(g) Asbestos-Cement-Board

Surfaces shall be dry and clean prior to application of the specified first-coat material. Oil and grease shall be carefully removed by the use of mineral spirits. Wire brushing will not be permitted. After the first coating has become dry, and prior to application of finish coats, touch-up coats shall be applied to all suction spots.

(h) Cotton or Canvas Covering over Insulation

Cotton or canvas covering over insulation on pipes, ducts, casings, tanks and other equipment in exposed locations shall be given two coats of alkyd resin type paint.

(i) Preparation of concrete & rendered surfaces for epoxy coatings

Concrete and rendered surfaces shall be thoroughly cured before the application of an epoxy filler primer or paint is begun. All surfaces to be protected with an epoxy paint system shall be prepared as described below, maintaining the sequence of operations indicated.

Areas of concrete contaminated with machine oil or grease shall be cut out as necessary to remove all traces of such substances and shall be made good with an approved epoxy mortar.

Areas contaminated with release agent shall be scrubbed with suitable emulsion cleaners and any mould growth shall be treated with water-soluble fungicide. All concrete and rendered surfaces to be coated shall be lightly blast-cleaned to remove the cement-rich surface layer, taking care not to roughen the surface unduly. Grit and detritus shall be removed by vacuum cleaning immediately prior to priming.

Blow-holes and honeycombed areas in the concrete which in the opinion of the Engineer are not capable of being satisfactorily leveled at the primer stage shall be filled with an epoxy mortar supplied by the coating manufacturer for the purpose. Such mortar shall be knifed into the surface to level the area and to leave no excess.

2.20.6 Paint Application

(a) General

Paint shall be applied by skilled painters, following manufacturer's printed instructions and using appropriate methods of application. To prevent formation of skins and loss of volition solvent, paint containers shall be covered when delays in application are encountered. Adjacent work and materials shall be protected by ample drop cloths or other suitable coverings. Spraying equipment shall not be employed in painting motors, electrical controllers, or other equipment where overspraying due to improper masking may be detrimental to equipment operation. Paint shall be thoroughly mixed immediately before use and at frequent intervals during application and shall be applied in proper consistency. The meeting line between colors shall be straight and sharply defined, with no blending, running or gaps. All coats of paint shall be applied uniformly and be free from sags, wrinkles, runs, holidays, smears, dirt, and shall not be defaced by spattered paint.

Paint drops and oversprays shall be removed before dry. The hiding shall be completed and each coat shall be so applied as to produce a film of uniform thickness. Special attention shall be given to insure that edges, corners, crevices, welds, and rivets receive a film thickness equivalent to that of adjacent painted surfaces. Metal or wood surfaces to be painted, and in, on, or adjacent to surfaces to receive water-thinned paints, shall be primed or touched up or both prior to and after application of water-thinned pains. Job mixed aluminum paint shall be used within four (4) hours. Aluminum paint not used within the specified time shall be discarded.

(b) Paint Properties, Storage, Mixing, and Thinning

At time of application, paint shall be protected from exposure of cold weather by storing in shelters to prevent freezing of the paint. Paint shall be thoroughly stirred, strained, and kept at a uniform consistency during application. Paints of different manufacturers or different type shall not be mixed together. Where approved by the Engineer as necessary to suit conditions of surface, temperature, weather, and method of application, the packaged paint may be thinned immediately prior to application if in accordance with the provisions of the manufacturer's directions, but not in excess of one-half (1/2) liter of suitable thinner per four (4) liters of paint. The irregular thinning for any reason shall not relieve the responsibility of Contractor to provide specified film thickness.

(c) Atmospheric and Ambient Conditions

Paint other than water-thinned coatings shall be applied only to materials which are completely free from surface moisture as determined by sight or touch and in which the subsurface moisture is non-existent or within the limits specified when determined by a moisture meter.

In no case shall paint be applied to surfaces upon which there is visible frost or ice. While painting is being done, the temperature of the surface to be painted and of the atmosphere in contact therewith shall be maintained at a minimum of 7C° and a maximum of 35C° During periods of inclement weather, painting may be continued be enclosing the surfaces with temporary shelters and applying artificial heat, provided the temperature requirements prescribed above are maintained throughout the drying period. Surfaces to be painted shall be protected from dust and dirt during painting and finishing.

(d) Time Scheduling of Painting

Surfaces that have been cleaned, pretreated, or otherwise prepared for painting shall be given a coat of the specified first-coat material as soon as practicable after such preparation has been completed but in any event prior to any deterioration of the prepared surface. Sufficient time shall elapse between successive coatings to permit proper drying. Paint shall be considered dry for recoating when it feels firm, does not deform or feel sticky under moderate pressure of the thumb, and the application of another coat of paint does not cause lifting or loss of adhesion of the undercoat.

(e) Requirements for specific Paints

a) Interior Emulsion Paint
First coat of interior emulsion paint shall be at such a rate as will effect sealing of the surface.

b) Exterior Emulsion Paint
At least 24 hours shall elapse before applying exterior emulsion paint over filler coat.

c) Signs
Two coats of Traffic Paint shall be applied. Time shall be allowed between coats to ensure drying.

(f) Painting of Above ground Steel Tank

a) Surface Preparation
Surfaces to be painted shall be cleaned of all mill scale and rust by sand blasting, power wire brushing, or other effective methods.

b) Priming
Immediately after surfaces have been cleaned, and before detrimental rusting or soiling can occur, a prime coat of a minimum dry film thickness of 0.025 mm of red lead base paint shall be applied to exterior metal surfaces. After the tank structure has been erected, welded, and tested, all areas on which prime coat has been damaged shall be cleaned and repainted with primer as specified above.

c) Finish Coats, Exterior
Exterior finish painting shall consist of two (2) coats of exterior oil paint, or equal.

(g) Method of Paint Application

a) Rollers for applying enamels shall have a short nap. Rollers for applying paints to masonry surfaces shall be a type designed for that purpose.

b) Brushes used for emulsion paint shall be soaked in water for a period of two (2) hours prior to brushing.

c) First coat of interior emulsion paint shall be at such rate as will effect sealing of the surface. The second coat of interior emulsion paint shall be applied so as to provide a uniform coverage of acceptable appearance.

d) Spray painting shall be done by the use of an air compressor and spray-gun.

(h) Multicolor painting shall be done with the use of compressor and spray-gun. The pressure shall be from 2.0 to 2.8 kg/cm2 for the first coat and 1.75 to 2.46 kg/cm2 for subsequent coats. The distance between the surfaces to be painted and the nozzle of the spray-gun shall be approximately 30cm. Spraying shall be done by gradual moving of spray-gun up and down until the surface has been coated completely.

(i) Bonn tile finish for cement plaster or asbestos cement board surfaces shall be applied by spraying equipment. Each coat shall be sprayed onto the surfaces in accordance with the printed instruction of the paint manufacturer, worked into voids and pores with a brush, and allowed to dry before spray spotting for vailing effect is accomplished. The final coats of clear acrylic resin shall be applied by means of roller or spraying equipment in accordance with the applicable requirements specified in paragraph entitled multi-color Painting. Finish coats shall be free from runs, sags and other defects.

(j) Epoxy coating concrete and rendered surfaces

In addition to the general requirements of this specification, the following conditions shall apply wherever epoxy coating work is being carried out:

The work shall be illuminated to the satisfaction of the Engineer.

Forced-draught ventilation to the approval of the Engineer shall be used wherever required for the needs of personnel or for drying out surfaces.

Operatives shall work in pairs.

The Contractor shall demonstrate all his methods, equipment and materials before any work commences. Sample areas of substrate shall be prepared and coated as required by the Engineer and for his approval.

There shall be strict control of surface cleanliness between primer and epoxy coating and between coats of the same. Vacuum removal of dust and sand-shall be employed and contamination shall be removed as specified in appropriate preparation clauses herein. Where dirt or dust has become trapped in the epoxy coating surface it shall be removed with suitable abrasive paper. The surface being coated shall be free of visible moisture throughout these operations.

Epoxy coating shall be applied only to clean, dry, primed or previously-coated surfaces. Any thick runs or collections of paint shall be removed before they harden.

No fewer than two coats shall be applied over the primer by airless spray, no fewer than three by brush.

Each coat shall be distinctly different in color from the primer or previous coat. The color of the final coat shall be as required by the Engineer.

Each coat shall be seen to have completely covered the preceding coat without misses or pinholes or any areas visibly low in thickness. A high-voltage pinhole detector shall also be used to determine the integrity of the coats.

The manufacturer of the coating shall stipulate primer and epoxy re-coating intervals for all curing temperatures likely to be encountered and these shall be adopted with a maximum tolerance of +4 hours. Where this is exceeded, the surfaces to be re-coated shall first be suitably abraded or treated with solvent to remove gloss and give key.

Wet-thickness gauges shall be used continually by the coating operators to check that sufficient coating is being applied to achieve the desired dry-film thickness.

No priming shall commence until the moisture content of the cemented surface is less than 5% measured by Wet Check moisture meter or other instrument approved by the Engineer.

The primer shall be a low-viscosity two or three-pack epoxy supplied by the manufacturer of the approved epoxy coating material. It shall have complete compatibility and inter-coat adhesion with the first coat of high-build epoxy paint.

The primer shall be applied by suitable nylon bristle brush or spray over the whole area to be coated at such thickness that it may then be squeezed into the pores of the concrete. Any excess shall be effectively removed before application of the high-build epoxy.

The Engineer may approve an alternative application method where the Contractor can demonstrate a suitable technique.

The protective coats shall be of an approved high-build epoxy, 2-pack or 3-pack, completely resistant to the corrosion conditions to be encountered. Certain types of coal-tar epoxy may be approved for this purpose where the Contractor has stated at the time of tendering the type of curing agent and coal-tar, with the percentage content of the latter.

The total dry-film thickness of the paint layer shall have a minimum value of 0.75 mm.

Wherever the paint inspection gauge has been used, and wherever the coating has been otherwise damaged, the surface shall be abraded for 50 mm around such damage and the area shall be touched in with not less than two thick applications to restore the coating integrity and thickness.

Adhesion tests shall be carried out on the cured coating surface using the test equipment supplied under the Contract. The resulting test specimens shall show no indication of poor adhesion to the substrate, residual laitance or intercoat adhesion weakness.

2.20.7 Surfaces Not to be Painted

The following listed items will not be required finish painting:

- Concrete and tile floors, unless otherwise directed.
- Aluminum or sized vapor barrier jacketing over insulation on pipes in unexposed locations not requiring color-coding.
- Unexposed interior ferrous surfaces, galvanized or not.
- Factory finish-painted equipment.
- Anodized an aluminum surfaces.
- Other items or surfaces so indicated not to be finish-painted.
- Exposed pre-cast concrete units.
- Concealed and exposed concrete surfaces having concrete sealer finish.

2.20.8 Cleaning

Cloths and cotton waste that might constitute a fire hazard shall be placed in closed metal containers or destroyed at the end of each day. Upon completion of the work, staging, scaffolding, and containers shall be removed from the site or destroyed in an approved manner. Paint spots, oil or stains upon adjacent surfaces shall be removed and the entire job left clean and acceptable.

2.20.9 Quality Control

The Contractor shall provide and maintain quality control for general painting. The Contractor shall ensure conformance to specifications and drawings with respect to construction, workmanship, finish, and functional performance; and record the inspection of all operations, including but not limited to the operations listed herein. Duplicate copies of records of inspection, as well as the records of corrective action taken shall be furnished as required by the Engineer and the Engineer's Representative.

- A check shall be made to insure that all materials comply with the approved samples immediately upon delivery to the site. Materials that do not comply shall not be permitted to be unloaded but immediately removed from the site.
- A list of all surfaces requiring paint shall be prepared, showing the surface preparation, type of paint, color, and number of coats required on each surface as specified. This checklist shall be used to insure that specifications are being followed.
- A check to insure exterior emulsion paint for concrete masonry units is mixed strictly in accordance with the specifications will be made.
- A check to insure cement-emulsion filler is vigorously scrubbed into the concrete-masonry-unit surface as specified, and is used in full strength and not diluted, and to insure that the filler coat and subsequent coat for concrete masonry units shall provide a waterproofed surface against driving rain.
- A check to insure that plaster surfaces are properly aged and dried before the application of oil or vanished base materials will be made.
- A check to insure that coating failures are satisfactorily corrected will be made.

2.20.10 Tests

Method of test for paint, varnish, lacquer and related material shall conform to follows.

ASTM A 90	Test Method for Weight of Coating on Zinc-Coated (Galvanized) iron or Steel Articles.
ASTM C884/C884M	Standard Test Method for Thermal Compatibility Between Concrete and an Epoxy-Resin Overlay
ASTM D 1006	Standard Practice for Conducting Exterior Exposure Tests of Paints on Wood
ASTM D 1014	Standard Practice for Conducting Exterior Exposure Tests of Paints and Coatings on Metal Substrates

ASTM D 1360	Standard Test Method for Fire Retard Paints (Cabinet Method)
ASTM D 1652	Standard Test Method for Epoxy Content of Epoxy Resins
ASTM D 3168	Standard Practice for Qualitative Identification of Polymers in Emulsion Paints
ASTM D 4142	Standard Guide for Testing Epoxy Resins

2.21 SAFETY LADDER (PE COATING)

2.21.1 General

This specification is purposed to define the production and the purchase of safety ladders required for the basic and execution designs of Sewage Improvement Project.

(a) Scope of this specification includes production, standards, quality test, delivery, and installation of the safety ladders used in manhole and underground facility.

(b) If manhole and underground facility depth is over 4 m, install safety net in ladder.

Types, standards, shapes, and quantities of the safety ladder and safety net shall be in conformity with the design document and Quantity of Bill

The Contractor shall submit production documents for the contract item to acquire approval from the construction supervisor before starting production.

2.21.2 Material

(a) The diameter of structural steels should be 18.5 mm to 50.0 mm with a tensile strength of 400 N/mm² or above and a coefficient of expansion of 10 % or above.

(b) The resin should exhibits good durability, chemical resistance, corrosion resistance, and impact resistance.

2.21.3 Production

(a) Composition: The safety ladder is composed of a special structural steel and a polypropylene.

(b) Size: The outside dimension of the safety ladder shall be in conformity with the design document.

(c) It should exhibits good durability, chemical resistance, corrosion resistance, and impact resistance by coating polypropylene on the special structural steel.

(d) A wave pattern should be applied to the inner portion to facilitate convenient hand gripping.

(e) The surface of horizontal bar that makes a contact with sole should have grooves to prevent slipping.

(f) The location of ladder should be identifiable at night by installing luminous prisms on the upper and lower portions of both sides.

(g) Safety net is made by Sus 304 50 mm

2.22 RIVERBED MAINTENANCE WORKS

2.22.1 General

(a) Applied Scope

This specification shall be applied to riverbed maintenance facilities to keep profile and transection in a river while slowing down riverbed slopes to maintain riverbed.

(b) Main Details

- Concrete riverbed maintenance facilities

- Natural riverbed maintenance facilities

- Block riverbed maintenance facilities

(c) Definition of term

- Riverbed maintenance facilities are classified into drop works and streambed works, depending on the size of drop head. They are also classified into concrete types, natural types and block types, depending on the type and materials used. In general, riverbed maintenance facilities consist of main body works, apron works, floor protection works, connecting wall and revetment works, and high-flow plain protection works.

- Drop works refer to riverbed maintenance facilities with large drop head (normally 50 cm or more).

- Streambed works refer to riverbed maintenance facilities without drop head or with very small drop head (normally less than 50 cm).

- Concrete types refer to the most generalized riverbed maintenance facilities whose main material is concrete in their body structure.

- Natural types refer to riverbed maintenance facilities whose main material is natural stone in the body structure.

- Block types refer to riverbed maintenance structures whose main material is block product (including fishway block) in the body structure.

2.22.2 Materials

(a) Stone

- Any stone used for stoke attachment materials shall have 100 MPa (1,000 kg/㎠) or more of compression strength, its absorption shall be less than 5%.

- Any stone for stone masonry shall be hard and solid and its length shall be 30~45cm.

- Cement for wet masonry shall abide by BS Standards or their equivalents or better.

(b) Concrete

- Cement shall follow the related regulations in "2.5. Concrete Works" in this specification.

- Aggregates shall be compliant with BS.

(c) Concrete Block

- Any concrete block shall follow the related regulation in "Concrete Revetment Block" in this specification.

- Any block product (including fishway blocks) shall not have any damage or crack in appearance.

- The compression strength of any block product (including fishway block) shall be 21 MPa (210 kgf/㎤) or more, provided that it may be increased in line with site conditions.

(d) Wooden Pile

- Any pile shall be made of raw pine trees whose skin is completely removed and it shall be a frictional pile without any adhesion.

- Preservation processing shall be done with creosote impregnated for underground and fresh water poles.

- Dimensions shall be applied to the length and diameter as clarified in design drawings.

- Although no adhesion is allowed, adhesion shall be made under the approved method by the construction supervisor if it is stated.

- The end of a wooden pile shall be formed into complete contact to the supporting area or attach the welded steel.

- The head color of a pile shall be the color of the formed or welded steel.

2.22.3 Construction

(a) Concrete Riverbed Maintenance Facilities

(1) Main Body Works

a) General

- The main structure shall consist of concrete and it shall be safe from collapse, activity and sinking.

- The drop head in the main structure shall be determined in compliance with hydrological and structural safety as well as site condition, but it shall be limited within 1.0m. If the drop head height is 1.0m or more, multi-step drop head works shall be planned and the drop head of each step shall be limited within 1.0m.

- The width of levee crown in the concrete body structure shall be at least 1.0m, where the slope in the upstream shall be 1:0~1:0.5 and the slope in the downstream shall be installed slower than 1:0.5.

- The embedding shall be sufficient to prevent riverbed from scouring.

- As the connection between the main structure and revetment may be easily damaged by large flow, the thorough constructions shall be required.

b) Concrete works

- Close attention shall be paid to the construction process to prevent the main structure from collapse due to the cavity under the main structure floor and scouring in the downstream of the apron.

- Concrete works shall be dry construction by cofferdam.

- Any material with large water permeability such as pebbles or gravels shall not be used in the foundation process like other river structures to prevent piping under the foundation bottom due to the penetrated flow, and the accurately driven piles are important if any sheet pile is used for water shielding.

- As the surrounding ground may be weakened during the bed excavation despite the sufficient of bearing capacity in the foundation and the unequal settlement may occur from the weakened ground when the gush-out water is drained, the foundation processing shall be done sufficiently to prevent them.

- If it is difficult for sheet piles to be driven into the foundation, concrete barrier walls shall be constructed. As the surrounding ground may be weakened by excavation under such a circumstance, any unequal settlement shall be prevented during the refilling.

- During apron works, stone pitching shall be carried out in a proper size, if necessary, to increase dissolved oxygen in the water by aeration and improve water quality, while preventing the drop head by the scouring at the downstream end due to the embedding in a certain depth for the downstream end.

- Stone pitching shall adopt a zigzag alignment rather than a liner alignment, while maximizing aeration effect by the installation of stones in various sizes.

(2) Floor protection works

- Floor protection works shall have the installations under the planned riverbed height after riverbed variations are predicted and riverbed is stabilized in the future.

- If the current riverbed is higher than the floor protection works, the entire downstream bed shall not be excavated but the excavation shall be done from the end of the floor protection works to the proper section, and connected to the current river channel.

- As the floor protection works of the riverbed maintenance facilities are affected by erosion and traction by flow, they shall be continuously maintained after the construction.

- Any matter not mentioned in this section shall follow the related regulations in “Main Body Works of Concrete Riverbed Maintenance Facilities” in this specification.

(3) Connecting revetment works

- The connecting revetment shall be constructed in a structure to prevent shore or levee from scouring due to flow.

- The main structure shall be separated from the connection of the revetment in the riverbed maintenance facilities to make the connecting revetment become a structure to prevent damage to the levee or reservoir channel.

- The connection between the connecting revetment and main structure in the riverbed maintenance facilities shall have the close relationships in a structure to prevent the levee from collapse or reservoir revetment from loss due to the penetrating flow.

- The bottom compaction shall be installed in the front of the revetment in the upstream and downstream of the riverbed maintenance facilities, to prevent them from scouring.

(4) High-flow plain protection works

- A structure with proper coarseness is desirable to reduce the flow velocity while it is being stabilized by the surrounding scouring like the floor protection works.

- The high-flow plain protection works shall be constructed up to the upstream and downstream floor protection work of the drop head works.

(b) Natural Riverbed Maintenance Facilities

(1) General

- Natural riverbed maintenance facilities consist of natural rocks, wooden piles and vegetation, and they shall be safe from collapse, activity and sinking.

- Natural riverbed maintenance facilities shall be constructed in consideration of water quality improvement by aeration, biological habitation or migration in the river, as well as the functions to maintain the riverbed using natural rocks and wooden fence instead of concrete materials.

- Natural riverbed maintenance facilities shall keep the downstream slop slow to about 1:20 to secure the function of rapids, while enabling the migration of fishes, amphibians and reptiles.

- Natural riverbed maintenance facilities shall be constructed in consideration of water flow in the river and size of natural rocks to stabilize flow velocity, as well as functionality of environment and ecosystem.

- Natural rocks and foundations shall be constructed stably to prevent any loss during flooding, and continuous maintenance shall be required in preparation of loss of natural rocks consisting of the main structure after construction.

- Any matter not mentioned in this section shall follow the related regulations in “Main Body Works of Concrete Riverbed Maintenance Facilities” in this specification.

(2) Stone pitching

- Any construction using stones shall be carried out by dry construction with cofferdam.

- Stone pitching shall be done on the even surface of riprap stones and concrete as the foundation works for the main structure.

- No unequal settlement shall occur from the slope of stone pitching after construction, and the longitudinal direction of pitched stones shall be perpendicular to the slope direction.

- If the river flow is fast or the river slope is stiff, the wetted pitching shall be constructed with backfilling using concrete mortar.

- If the river slope is slow, the dry pitching shall be constructed for backfilling using the broken pebbles and gap-filling gravels.

- The foundation of stone pitching shall be constructed strongly to prevent any unequal settlement by the flow penetration.

- As the pitching stones or backfilling pebbles may be removed by flow In case of dry pitching, the seaming section shall be well interlocked by the skilled stone workers.

- Mortar shall be filled in the seaming section after pitching stones are aligned in parallel on the foundation concrete to make the pitching surface even in the wetted pitching.

- Rock protection on embankment slopes and around structures shall be to the lines and levels shown on the contract Drawings. The terms "tipped rock" and "pitching" refer to the manner in which the rock is placed.

- The rock fragments shall be well graded with not more than forty per cent (40%) of the rocks being smaller than the stated nominal size. The shape of the rock shall be roughly uniform with no dimension less than sixty percent (60%) of the largest dimension. The individual rock pieces shall be dense, durable and abrasion resistant.

- The Contractor shall submit bulk samples of not less than 2 m3 of each class of rock for approval by the Project Manager prior to placing. These samples shall be retained for comparison with material being placed in order to ensure a reasonable degree of uniformity within each class.

- The base on which rock protection is to be placed shall be compacted and trimmed to the lines and levels shown on the drawings. Where two or more classes of rock are specified, the lower layers shall be completed to the Engineer's approval before the placing of subsequent layers.

- Tipped Rock shall be tipped directly into place and roughly trimmed to the required profile. The thickness, lines and levels of tipped rock is shown on the Drawings.

- Pitching will be used where a finished horizontal or inclined surface is required. It shall consist of hand placed stones, with spalls wedged into the interstices to produce an even surface, without projection above the neat lines shown on the Drawings. Care shall be taken to ensure that the stones are well bedded and the percentage of spalls shall not exceed forty percent (40%) of the total rock volume. Pitching on slopes shall be built upwards from the toe, unless otherwise directed by the Project Manager. A coping consisting of large flat stones shall be laid along the top of stone pitching on slopes to produce a firm edge.

Tipped Rock and Stone Pitching shall consist of selected hard durable rock free from weathered or decomposed parts to the approval of the Engineer, containing no flaky stone and being well graded within the limits shown below.

Class	Size of stone	Percentage by weight

	d (mm)	smaller than stone sized
A	300	100
	125	40-55
	45	0
B	150	100
	63	40-55
	31.5	0
C	63	100
	22	60-85
	8	20-40
	4	0
Class	Size of stone d (mm)	Percentage by weight smaller than stone sized
D	31.5	100
	16	50-80
	8	20-50
	4	0
E	350	100
	200	0
F	225	100
	90	35-55
45		0
G	850	100
	500	30-60
	300	0

- Tipped rock / stone pitching shall be placed in an approved manner in order to produce a uniform well knit unsegregated layer in which all sized are held in position.

- Other construction instructions shall follow masonry works and any matter not mentioned in this section shall follow the related regulations in "Masonry Works of Slope Covering Works" in this specification.

(3) Masonry Works

- If the river slop is 10% or more, masonry works shall be constructed for stone masonry on the surface after applying gravels or pebbles on the internal center in the main structure works.

- The dry pitching shall be constructed using gravels or pebbles in the internal center of the main structure in case of small rivers or creeks.

- The wet pitching shall be constructed in any rapid rivers.

- The foundation shall be strongly constructed to prevent any unequal settlement.

- The embedding shall be sufficiently done and the constructed surface shall be made even to prevent the riverbed from scouring.

- The thickness of backfilling concrete shall be constructed in 30~60㎝ or more.

- Attention shall be paid to the prevention of settlement in the filling and backfilling during stone masonry.

- The broken stones shall be laid down as their valleys are interlocked with each other, and 1/10 or more of the stone length shall be interlocked in the seaming section.

- Attention shall be paid to the construction to prevent any projected stone in the pitching for the acute section in the upstream or downstream on the floor of riverbed maintenance facilities.

- The backfilling rubble stones shall be placed in the dry pitching, and the skilled stone workers shall carry out construction for the good interlocking in the seaming section to prevent stones or backing rubble stones from being removed by flow as the gap between stones shall be processed by the gap-filling with small stones.

- Drain works shall be constructed, if necessary.

- Any matter not mentioned in this section shall follow the related regulations in “Slope Covering Works” in this specification.

(c) Block Riverbed Maintenance Facilities

(1) General

- Block riverbed maintenance facilities shall consist of blocks (including fishway blocks) and concrete foundations, which shall be safe for collapse, activity and settlement.

- Matters on excavation of structures and block foundations shall follow the related regulations in “Civil Engineering”.

- The foundation of block riverbed maintenance facilities shall have the foundation concrete in 200~300 mm thickness on the compacted ground to stabilize blocks or the installation of mat on the ground.

- The concrete pool or support pond shall be installed on the bottom of block installation to prevent the bottom from scouring with a role of supports.

- Block riverbed maintenance facilities shall have the downstream slop in about 1:20 to enable migration of fishes.

- As block riverbed maintenance facilities may interrupt migration of fish due to the flowing sand sedimentation, the continuous maintenance efforts will be necessary after construction.

- Any matter not mentioned in this section shall follow the related regulations in “Concrete Riverbed Maintenance Facilities” in this specification.

(2) Concrete block works

- Concrete block construction shall follow the related regulations in “Concrete Revetment

Block" in this specification.

- The dry construction using cofferdam is desirable in consideration of mutual connections between blocks if any heterogeneous concrete blocks are used.

- The coarseness coefficient of concrete blocks shall be proper for the current river bed.

- The size of concrete blocks shall be stable for the flow velocity.

- The flexibility of concrete blocks shall be secured.

- Close attention shall be paid to refilling after even excavation on the foundation floor because the installation shall be done horizontally.

- The comparatively good place shall be selected for the foundation. If the installation is done unavoidably on the fragile ground, the surface processing shall be done including the replacement of sand in 1.0 m or more on the top layer.

- Blocks shall be mutually connected and connection nuts shall not be loosened. The connection between blocks shall be filled with mortar to become a strong and uniform structure.

- The habitation and migration of fishes shall be done easily by installing pools or supporting ponds on the block bottom. Gravels shall be placed in the pools and ponds to keep natural conditions.

3. BUILDING WORKS

3.1 BLOCKWORK-PLASTERING

3.1.1 Pre-cast Concrete Blocks, Sandcrete Blocks

(a) Precast concrete blocks and sandcrete blocks shall be manufactured locally with aggregates, sand and cement in an approved vibrating pressure machine. The mix proportions shall comply with DIN 1045. The sand shall have the following grading:

Sieve Size [%]	Passing [% per weight]
2.4	- 100
1.2	95 - 100
0.6	25 - 85
0.3	5 - 50
0.15	0 - 10

(b) The blocks shall be hard, sound, with sharp well defined arises, and shall be 40 cm long by 20 cm high by the specified thickness, unless otherwise instructed by the Engineer. The sandy bricks shall be 25 cm by 12 cm by 6 mm of uniform colour and shall comply with the relevant Malawi Standard Specifications.

(c) Immediately after moulding, the blocks shall be placed on a clean level pallet and shall be cured by being continuously sprayed with water or other approved means.

(d) For a sample out of twelve blocks, randomly selected, the average compressive strength shall not be less than 3 N/mm2, and no block out of the twelve shall be less than 2.4 N/mm2. If these requirements are not met, the whole batch from which the twelve blocks were selected will be rejected.

3.1.2 Workmanship

(a) All block work shall be set out and built to the respective dimensions, thickness and heights as shown on the drawings.

(b) All blocks shall be carefully handled to prevent damage and protected as necessary. No cracked, chipped or broken block will be used in the works.

(c) In dry weather, the suction rate of all concrete blocks shall be adjusted by wetting before being used, and the tops of walls left unfinished shall be wetted before work is recommenced.

(d) All blocks shall be well buttered with mortar after being laid and all joints shall be thoroughly flushed up as the work proceeds.

(e) Block work shall be carried up in a uniform manner, no one portion being raised more than one meter above another at one time. All perpends, quoins etc., shall be kept strictly true and square and the whole properly bonded together and levelled round at each floor or agreed height. Bats shall not be used except where required for bonds. A full joint of mortar is to be made where block work abuts concrete or masonry.

(f) Jambs of openings in hollow block walling shall be built-in solid blocks.

(g) Stainless (galvanized) steel anchor ties to connect block walls to concrete columns shall be dovetail slots, with prior approval of the Engineer.

3.2 MORTARS AND PLASTERS

3.2.1 Mixing

(a) The mixes of mortars and plasters for block work, plastering and for external rendering shall be as per the following table:

Designation	Mix Proportions		
Cement Mortar	Cement (Vol.)	Lime (vol.)	Sand (vol.)
i	1	1/4	3
ii	1	1/2	4
iii	1	1	5
iv	1	2	8

(b) The ingredients for cement mortars shall be measured in proper gauge boxes on a boarded platform, the ingredients being turned over twice dry and twice whilst water is added through a sprinkler rose. Alternatively, mixing may be by means of an approved mechanical batch mixer.

(c) Cement and sand mortar mix shall be used within 2 hours after starting addition of water, any amount of mix remaining should be collected and disposed.

(d) Mortar plasticiser shall be of an approved make and shall be used in the proportions and manner recommended by the manufacturer. The proportions of the mortar mix shall if necessary be adjusted in accordance with the manufacturer's recommendations.

(e) Where coloured mortar or rendering is specified the pigment shall be of an approved manufacture and shall not be injurious to other ingredients of the mortar. It shall be mixed with care to ensure even colouring throughout the mixture and a sufficient quantity shall be made to ensure completion of an area of rendering in one operation.

3.2.2 Finishing

(a) The preparation of the surfaces for plastering, includes raking out joints of concrete surfaces or block work to form key, dubbing out all uneven surfaces as required, temporary rules and boards, working around pipe clips and other similar obstructions, working behind pipes.

(b) All surfaces are to be finished true and smooth.

(c) External angles, where not protected by metal angle beads, shall be properly formed rounded angles to 10 mm radius unless otherwise directed.

(d) All joints between block walls and concrete members, all routes of electric or sanitary piping should be covered by 20 cm wide metal lath strip; this will be included in the rates.

(e) The prices shall include for 1 m x 1 m sample panels if so directed by the Engineer.

(f) Plasters and Mortars shall be to the grades and mix proportions specified.

(g) Plastering to internal walls and surfaces shall be composed of the layers, as hereafter detailed, to make up the complete thickness of 15 mm.

(h) Backing coat shall consist of approximately 10 mm thick cement mortar Grade "C" and scratched to form key.

(i) Finishing coat shall consist of a 5 mm thick layer mortar Grade "C" and finished with a steel float to approval.

(j) Cement rendering shall be cement mortar Grade “A” and shall be applied in two or three coats. Undercoats shall not exceed an average thickness of 10 mm and finishing coats an average thickness of 6 mm. Two-coat rendering shall be to a total thickness of 16 mm and three coats rendering to a total thickness of 25 mm.

(k) Where rendering is to be applied to concrete surfaces such faces shall be suitably treated to provide an adequate mechanical key for the rendering.

(l) The surface of brickwork block work or masonry to be rendered shall be thoroughly prepared before the first undercoat is applied by raking out the joints to form an efficient key for rendering.

(m) Surfaces shall be thoroughly brushed down to clean off all dust and loose material. Particular attention shall be paid to the removal of mould oil or other deleterious substances prior to rendering. Each undercoat shall be scored to form an adequate key for subsequent coats. The surface of block work shall be thoroughly wetted with fresh water before rendering is applied.

(n) Each rendering coat shall be kept moist for at least 48 hours and then given adequate time to dry out thoroughly before the application of any subsequent coats. The surface shall then be wetted immediately before the application of any further coat.

(o) The finishing coat shall have a steel float finish to true planes and regular curves and to an even and polished surface. Arises shall be rounded and in true alignment and a hollow fillet shall be run at internal angles.

(p) The finished rendering shall be protected and cured as specified for concrete.

3.3 GLAZING

3.3.1 Materials

(a) Clear plate glass shall be of a quality as locally available and as directed by the Engineer.

(b) Clear plate glass shall be to the thickness given on the drawings and the Bills of Quantities.

(c) Wired reinforced glass shall be 7 mm thick.

3.3.2 Workmanship

(a) The glass shall be cut to sizes with a small clearance and shall be installed in accordance with the manufacturer's drawings and recommendations as approved by the Engineer.

(b) The glass shall be cleaned inside and outside and all cracked and broken glass replaced before handing over the Works.

3.4 METAL ROOF WORKS

3.4.1 Material

(a) Light metal plates

(1) Quality specifications
Light metal plates shall be light corrugate plates, templates or semi-lard band templates, and the designation of their types shall be done in accordance with specifications on drawings or construction specifications.

(2) Thickness of plate
Table 1 shall be the standards for the thickness of plates and the designation of their types shall be done in accordance with drawings or construction specifications, provided that Type B shall be applied when there is no provision on drawings or construction specifications.

Table 1 Thickness of Light Metal Plates

Type	Type A	Type B	Type C
Thickness	0.6 mm	0.5 mm	0.4 mm

(b) Fixing ironware and others

(1) Types of fixing ironware
The fixing ironware of light metal jointing plates shall include light metal nails, stainless steel nails, brass nails or cadmium plated iron nails and galvanized iron nails.

(2) Length of fixing nails
The length of fixing nails for flat plates or strap plates shall be 24 ~ 30 mm.

(3) Fixing ironware for corrugate plates and others
The fixing ironware for corrugate plates and ribbed templates (hereinafter referred to as ‘Templates’) shall be done in accordance with Table 2 and their types shall abide by provisions on drawings or construction specifications, provided that Type B shall be applied if there is no provision therein.

Table 2 Fixing Ironware (for Wooden Purlins)

Type	For small corrugate plates (mm)	For large corrugate plates (mm)

	Type A	Type B	Type A	Type B
Nails	4 ψ × 50	3.5 ψ × 40	4.5 ψ × 50	4 ψ × 40
Screw nails	5 ψ × 40	4 ψ × 30	6 ψ × 50	5 ψ × 40

(4) Hook bolts

If a purlin is made of steel, hook bolts (diameter 4~5 mm), hanging plates (thickness 1.2 mm, width 20 mm) and clip (thickness 2 mm, width 25 mm) with others shall be used.

(5) Shape of fixing ironware

Fixing ironware shall be selected, which is suitable for corrugate shape, and washers shall have thickness and diameter suitable for the diameter of fixing ironware. In addition, their supports shall adopt felt materials having the same diameter as washers, where rubber or asphalt in thickness 2 mm or more is penetrated.

3.4.2 Installation

1) General

(a) Jointing and lapping engineering method

The jointing and lapping engineering method shall be done in accordance Table following:

Division Engineering Method	Lapping Section	Jointing Section	Plate End
Standard Engineering Method	Radius is interlocked and lapped according to materials and plate thickness.	Clamp joint, 12~15 mm is applied to the lapped width, unless it is otherwise provided on drawings or construction specifications.	Lapped to the inside.
Special Engineering method	In accordance with drawings, construction specifications or approval by the person in charge. Template jointing shall be done in accordance with the predefined engineering method.		

(b) Lapping of flow direction

The lapping width of flow direction for corrugate plates shall be done in accordance with drawings or construction specifications, provided that it shall be done in accordance with Table 15020.2 if there is no specific provision.

(c) Jointing of Width Direction

The jointing of width direction shall be done in accordance with drawings or construction specifications, provided that it shall be done in accordance with Table following, depending on the roof pitch if there is no specific provision.

Pitch	Less than 3/10	3/10 or more	4/10 or more
Engineering Method	Soldering	Clamp joints, watertight painting for jointing	Dual clamp joints, watertight painting for

		sections	jointing sections

(d) Lifting of plates

For the standard for the joint of flow direction, the effective lifting shall be made in 25 mm or more for strap plates and flat plates, 18 mm or more for templates, and 9 mm or more for corrugate plates.

(e) Arrangement of clamps

When a plate is attached to the base, light metal clamps (width 25 mm) shall be used and the binaural piece shall be attached in the interval for the arrangement of fixing ironware, which is a piece per every 450 mm. However, instructions by the person in charge shall be followed for the reinforced templates and the interval for the arrangement of shorter plates shall not exceed 450 mm.

(f) Bending of plates and clamps

The bending of plates and clamps shall be done in accordance with this Construction Standard Specifications 16000 (Metallic Construction).

(g) Wooden floor

When the floor is wooden, the insulation shall be in principle done with asphalt roofing or neutral coal tar.

(h) Steel frame floor

When the floor is steel frames, the insulation painting shall be done for the contact of purlins and joint plates.

(i) Floor of mortar or concrete

When the floor is mortar or concrete, the insulation shall be done with asphalt waterproofing layers.

(j) When fixing ironware other than light metals is used

When fixing ironware other than light metals is used, the insulation painting shall be done for any area exposed to rainfall.

(k) When watertight characteristics are necessary

Watertight engineering methods such as brazing, watertight caulking or watertight painting shall be applied to any place necessary for watertight characteristics for joints and nailing spots.

(l) When fixing with nails or bolts is done

When fixing with nails or bolts is done, flexibility shall be given for temperature of plates by enlarging holes a little more.

(m) Joint of clamps

Light metal clamps shall be used to fix the plate end and the joint of clamps shall be done in accordance with drawings or construction specifications, provided that butt joint shall be applied if there is no specific provision and 2 light metal (or cadmium / galvanized iron) nails shall be driven per 450~500 mm interval.

2) Various Engineering Methods

(a) Flat joint

(1) Size of joint plates
Flat plates or strap plates shall be used for joint plates, where 4 planes shall be clamp joint. The standard width for a sheet of a plate shall be around 450 mm.

(2) Jointing of joint plates
Watertight painting for dual clamp folding shall be the standard for the joint of jointing plants. Watertight painting on water caulking shall be done during clamp folding.

(b) Lozenge jointing

About 450 mm shall be the standard for a side of a sheet for the jointing plate, and the jointing section shall be done with dual clamp folding and watertight painting.

(c) Strap plate jointing and ribbed seam jointing

(1) Jointing of joint plates
The jointing of longitudinal direction for jointing plates shall be lifted bending, pushed bending, inserted bending and valley lapping. When ribbed seam is used, the lifted section shall be 40 mm or more for waterproofing.

(2) Fixing of strap plates
Strap plates shall be fixed on the floor per about 450 mm and anything with clamp jointing shall be jointed with clamps and the lapping shall be done with nailing or bolt fastening.
When any wooden ribbed seam is used, fixing may be done with anti-corrosive light metal nails only for the lifted section of 25 mm or more to the side.

(3) Consideration for expansion and shrinkage
Space shall be placed in consideration of expansion and shrinkage by narrowing down the bottom end of ribbed seam or hooked attaching to the jointing plates, where temperature variations are severe.

(d) Jointing of corrugate and flat plates

(1) Fixing
Fixing for the jointing of corrugate plates and flat plates shall be done on the ridge of valleys. The standard interval shall be done in accordance with Table 15030.5, when the plate thickness is 0.5 m. The interval shall be made 1.3 times as large as those of Table 15030.T for plate thickness of 0.6 m, and 0.8 times as large for plate thickness of 0.4mm. The area with less snow (maximum snowing of 3 cm or less) or the minor structure without concern of damage by storm may increase the interval by 2 times.

Distance of Flow Direction		About 450	About 600
Distance of Width Direction	Large valley	4 valleys (300)	3 valleys (230)
	Small valley	8 valleys (250)	6 valleys (190)
	Template	About 300	About 200

(2) Lapping of width direction
Lapping of width direction for corrugate shall be 2 valleys for small valleys and 1.5 valleys or more for large valleys, and the number of valleys shall be instructed by the person in charge for templates.

(3) Lapping of flow direction
Lapping of flow direction shall be done.

(4) If fixing is done to the roof sheets
Although corrugate plates shall be fixed on purlins in principle, they may be fixed to the roof sheets when roof sheets in thickness 18mm or more are used.

3) Engineering Method for Each Section

(a) Wrapping of roof ridge

(1) Wrapping plates
Strap plates shall be applied to wrapping plates, if possible, and the jointing shall be reduced. The joint shall be clamp folding or clamp attachment.

(2) Roof sheets shall be used in around 100 mm for shaped wrapping sheets on the roof bridge for the interface to top of sheets in jointing corrugate plates and templates during the jointing of corrugate plates and templates. The top on the roof sheets shall keep valleys lifted up and the weathered slope shall be attached.

(3) For the jointing of flat plates
For the jointing of flat plates, the top shall be lifted up in 20 mm or more and the wrapping to the bottom of wrapping plates for the roof ridge shall be made.

(4) For the jointing of ribbed seam
For the jointing of ribbed seam, the top of jointing plates shall be lifted up in 40 mm or more and their corners shall be finished in watertight engineering. The wrapping plates shall be lapped in about 7 5mm on the roof ridge in accordance with the jointing of corrugate plates.

(b) Joint end

(1) For the jointing of corrugate plates and templates
For the jointing of corrugate plates and templates, the lapped weatherboards shall be lifted up in 120 mm or more to the wall side in accordance with the wrapping engineering for the roof ridge, and wall sheets shall be lapped in about 75mm.

(2) For the jointing of flat plates
For the light metal flat plates or strap plates in the jointing of flat plates, the top shall be lifted up in 40 mm or more, and wall sheets shall be fixed in clamp folding or clamp fixing.

(3) For ribbed seam roofing
Any ribbed seam roofing shall be done in accordance with 3.3 (Engineering Method for Each Section).

(c) Gable side and end

(1) For the jointing of corrugate plates and templates
For the jointing of corrugate plates and templates, the shaped weatherboard in line with corrugate plates and templates shall be lapped in 100 mm or more.
Both ends shall be done with clamp strap attachment. When gable plates are wrapped, weatherboards shall be folded and attached along the valley of gable sheets, and the weathered slope shall be fixed with clamps and lowered 15 mm or more from gable plates.

(2) For the jointing of flat plates

For the jointing of flat plates, the bottom shall be fixed in dual clamp folding and clamp fixing to the top of gable wrapping plates fixed with clamps in accordance with 3.3 (Engineering Method for Each Section).

(3) For the jointing of ribbed seam roofing
For the jointing of ribbed seam roofing, the wrapping plates for the ribbed seam roofing and wrapping plates for gables shall be done with the eared clamp folding and clamp fixing.

(d) Joint with walls

(1) For the jointing of corrugate plates and flat plates
For the weatherboards in jointing corrugate plates and flat plates, the weathered slop shall be attached to the top, lifted up 100 mm or more to the walls, and the appropriate weathered slop (0.2 or more) shall be attached along the jointing plates. 1.5 valleys for large valleys and 3 valleys or more for small valleys shall be lapped. The weatherboards shall be lapped about 100 mm for flat plates with the proper weathered slop at the end.

(2) For the jointing of flat plates
For the jointing of flat plates, the weathered slop on the top shall be attached and lifted up 25 mm or more, so that the weatherboards are lapped and attached in accordance with 3.3 (Engineering Method for Each Section) C-1) or lifted up 50 mm or more for the fixing to the walls with clamp folding or clamp fixing, or lifted up about 40 mm with the attachment of weatherboards to the inside in 50 mm.

(3) For the jointing of ribbed seam roofing
For the jointing of ribbed seam roofing, it shall be lifted up 40 mm or more by the clamp fixing, which shall be fixed by the eared clamps with the weatherboards lifted up 75 mm or more, or the weatherboards (about 60 mm) with the weathered slops shall be lapped and attached.

(e) Edge of eaves

(1) For the jointing of corrugate plates and templates
The edge of eaves for the jointing of corrugate plates and templates shall be projected about 30 mm and fixed from the bottom with clamp fixing, where the nailing shall be done to the sheets of eaves near the top. The wrapping boards for eaves shall be done with the clamp folding to the bottom plates in 120 mm or more and the rivet jointing in light metal shall be done for the elements.

(2) For the jointing of strap plates
For the jointing of strap plates, the edge of eaves shall be finished with clamp and the placing plates (bottom plates) may be omitted.

(3) For the jointing of flat plates
For the jointing of flat plates, the throating shall be attached and the edge of eaves shall be wrapped down or the clamping folding shall be done onto the top of the eave end plates fixed to the clamps.

(4) For the jointing of ribbed seam roofing
For the jointing of ribbed seam roofing, the edge of eaves shall be fixed with clamps and both the jointing plate bottom shall be fixed with the clamp folding with the use of 60 mm~100 mm wide strap plates as the placing plates whose upper corners are fixed with clamps.

(f) Side valley

(1) Engineering method for side valley
When any side valley is placed, the throating shall be attached to the top of corrugate plates and lifted up 60 mm or more, and the eared clamp folding shall be done with the bottom plates which are inserted and lapped 40 mm or more into the roof sheets.
The roof plates shall be lapped down 25 mm or more to the side of valley with the clamp fixing. The side of walls shall have the attachment of weathered slops on the back, lifted up 100mm or more, and the wall plates shall be lapped down 75 mm or more.

(2) For the jointing of corrugate plates
For the jointing of corrugate plates, the roof plates shall be folded down along the lifting of the roof corrugate plates in 1.5 valleys for small corrugate plates and 50 mm or more for large corrugate plates. Or, 2 valleys for small corrugate plates and 1.5 valleys or more for large corrugates shall be lapped and inserted into the bottom of roof plates, and the weatherboards shall be fixed with the eared clamp folding and clamps to the corrugate plates.

(g) Jointing of roof valleys

(1) For the jointing of flat plates
For the jointing of flat plates, both ends of corrugate plates shall be folded to roof plates with clamp folding or lifted up 40mm or more, and both the jointing plates and their ears shall be all done with watertight engineering method by the clamp folding.

(2) For the jointing of corrugate plates and templates
For the jointing of corrugate plates and templates, the bottom plates shall be elongated and extended to be lapped and inserted into the bottom of roof plates as long as the lapped section along the roof pitch in accordance with the preceding clause, and the roof plates shall be fixed with the watertight engineering method.

3.5 METAL WORK

3.5.1 Material

(a) Structural steelwork shall comply with recognized standards for general structural purposes.

(b) Bolts, washers etc. for use with structural steel shall be black bolts. Fastenings, including bolts, for use with materials having a galvanized finish shall be sheradised or have an alternative approved protective metal coating.

(c) Before ordering or fabricating any item of metalwork, the Contractor shall submit to the Engineer for his approval shop drawings showing all details and dimensions required for fabrication, assembly and erection. Fabrication shall only commence after the approval of the Engineer has been obtained.

(d) Angles, channels, flats and all standard steel sections shall be to the sizes given on the drawings.

(e) Angles or channels used for framing of openings in concrete structures or for guides shall be provided with steel fixing lugs securely welded to the frame or guide prior to galvanizing.

(f) All steel shall be treat corrosion protection

3.6 LADDERS, STAIRS, HANDRAILS AND OPEN FLOORING

(a) Unless otherwise stated, all steelwork shall be hot dip galvanized.

(b) Steel runged ladders shall conform to international safety standards and as amplified by the details given in the Bill of Quantities or as shown on the drawings.

(c) Safety hoops and stringer extensions shall be included where required for safety, unless specifically excluded by details given in the Bill of Quantities or on the drawings.

(d) Suitable support stays shall be provided for fixing the ladder to the supporting structure so that there is a minimum of 200 mm clearance behind the rungs. These connections shall be of the type, which bolt to the supporting structure.

(e) Handrails and stanchions shall be safe and stable and properly fixed to the concrete.

(f) Handrails shall be prefabricated of steel pipes of DN 50 or 65 mm nominal bore, cut to lengths and fixed by welding to the stanchions. Hand railing and fixings shall be designed to withstand a horizontal force at handrail level of 740 N/mr.

(g) Stanchions shall be as the handrails made of 50 or 65 mm nominal bore shank and be 1200 mm high. They shall be set in sockets cast in the concrete and grouted in non-shrink grout. Spacing shall be a maximum 1.500 mm. Side palm type of fixing will only be used where shown on the Drawings or approved by the Engineer.

(h) Open mesh (Grid Cover) or chequer plate flooring shall be of mild steel. The thickness of plate or construction of open mesh shall be of adequate strength to bear the load of not less than 5 kN/m2.

(i) In addition to the requirements of strength a minimum overall chequer plate thickness of 7 mm and an open mesh minimum member thickness of 3 mm shall be allowed.

(j) Where a welded construction is used to open mesh flooring the welding shall be continuous, heavy and on both edges of a joint.

(k) Metal flooring shall in all cases be supported by a properly formed and secured steel kerbing running continuously throughout the length supported. The flooring shall be provided with proper and adequate lifting handholds and where used on suspended supports adequate clips shall be used to prevent any movement of the flooring.

(l) Mild steel plating, open mesh and kerbing shall be hot dip galvanized after cutting, manufacture and complete fabrication.

(m) Where metal flooring is placed adjacent to a clear opening it shall include a 100 mm high kicking plate along the full length of the opening. Rates for such flooring shall include for kicking plate as described.

(n) Chequer plate covers over cables/pipes passage in transformer/generator rooms shall be non-slip pattern type and shall be set flush in mild steel frames provided with lugs for building in.

3.7 DOORS AND WINDOWS

3.7.1 Material

(a) Steel doors shall be of the hollow metal type constructed in standard profiles and sheet steel.

(b) The doors shall be provided with buffer strips fixed all around the frame.

(c) Windows and frames shall be manufactured of anodised aluminum, to the dimensions given on the Drawings. They should generally be supplied with one horizontally sliding sash complete with sash-bolt unless shown otherwise.

(d) All windows shall be designed to withstand wind pressures and to be dust proof.

(e) Openings in windows shall be provided with an aluminum fly-screen mesh. In offices the glass shall normally be 5 mm thick clear sheet glass.

3.7.2 Installation

(a) Doors and windows shall be installed plumb and true to line and shall operate smoothly.

(b) Doors and windows shall be such that glazing or re-glazing on site is possible without the need to remove the outer frame from the structure of the building.

(c) The Contractor shall submit details of manufacture including sections of all members and no orders shall be placed until such details have been approved by the Engineer.

(d) Weather stripping shall be made from material compatible with aluminum, be resistant to deterioration by weather conditions.

(e) All doors and windows shall be protected after installation and handed over in a clean and perfect condition on completion of the works.

3.8 PROTECTION

3.8.1 General

(a) The work detailed in this section refers only to protection applied at the manufacturer's works prior to delivery. The protection required subsequently is covered in Section Paintwork.

(b) All paints shall be obtained from one approved manufacturer, and applied strictly in accordance with the manufacturer's instructions. The source of supply shall not be altered without the Engineer's approval. The colour of the paints used shall be of different shades.

(c) After welding and fabrication, all weld areas shall be thoroughly cleaned and touched up as specified with the appropriate priming system.

3.8.2 Repair of Damaged Coatings

Any damage to the protective coating shall be made good as soon as possible, and shall not be left until the time of general finish painting. Damaged areas shall be cleaned down to bright metal by power wire brushing or sanding and feathered of to the surrounding area.

A new protective system shall then be applied generally following the requirements of the system originally applied, modified if necessary to comply with the recommendations of the manufacturer of the protective materials used.

3.8.3 Types of Protection

Unless otherwise specified on the Contract Drawings the various types of protection shall be applied as detailed below:

(a) Type A (hot-dip galvanized to give a minimum coating weight of 1200 gm/m2):

- All ladders, staircases, guardrails, guardrail standards, safety cages and open steel flooring and small bore pipe work;
- All small metalwork such as pipe supports, steel flooring supports and safety chains.
- All steelwork, which is in contact with potable water, or is in close proximity to potable water.

(b) Type B (zinc rich epoxy primer and heavy-duty epoxy coal tar):

- All steelwork, which is in contact with sewage, or is in close proximity to sewage, or is buried in the ground.

(c) Type C (zinc rich epoxy primer):

- All steelwork in buildings or otherwise which is exposed to the weather.

(d) Type D (metallic lead primer applied by brush to a minimum thickness not less than 75 μm):

- All steelwork, which is in buildings but protected by cladding.

(e) Type E (hand or tool cleaning to remove rust, grease etc. for all steel work, which is to be encased in concrete).

3.9 PAINTING

3.9.1 General

(a) Paint exposed exterior and interior plumbing, heating and electrical equipment, apparatus, conduits, pipes and fitting, supports and hangers and all other unfinished surfaces of mechanical and electrical work.

(b) Equipment In Finished Rooms: Paint wall grilles and diffusers, door louvers, panel board fronts and other equipment having a factory finish, occurring in rooms other than storage, mechanical and custodial.

(c) Work includes field painting of exposed bare and covered bare and covered pipes and ducts (including color coding), and of hangers, exposed steel and iron work, and primes or factory painted metal surfaces of equipment installed under mechanical and electrical work, except as otherwise indicated.

(d) “Paint” as used herein means all coating systems materials, including primers, emulsions, enamels, stains, sealers and fillers, and other applied materials whether used, as primer, intermediate or finish coats.

(e) Surfaces To Be Painted: Except where natural finish of material is specifically noted as a surface not to be painted, paint exposed surfaces whether or not colors are designated. Where items or surfaces are not specifically mentioned, paint the same as similar adjacent materials or areas. If color or finish is not designated, Architect will select these from standard colors or finishes available.

Following categories of work are not included as part of field-applied finish work.

(1) Concealed Surfaces: Unless otherwise indicated, painting is not required on surfaces such as walls or ceilings in concealed areas and generally inaccessible areas, foundation spaces, furred areas, utility tunnels, pipe spaces, duct shafts and elevator shafts.

(2) Finished Metal Surfaces: Unless otherwise indicated, metal surfaces of prefinished aluminum, anodized aluminum, stainless steel, chromium plate, copper, bronze and similar finished materials will not require finish painting.

(3) Operating parts: Unless otherwise indicated, moving parts of operating units, mechanical and electrical parts, such as valve and damper operators, linkage, sinkage, sensing devices, motor and fan shafts will not require finish painting.

(d) Following categories of work are included under other sections of these specifications.

(1) Shop Priming: Unless otherwise specified, shop priming of ferrous metal items is included under various sections for structural steel, metal fabrications, hollow metal work and similar items.

(2) Unless otherwise specified, shop priming of fabricated components such as architectural woodwork, wood casework and shop-fabricated or factory-built mechanical and electrical equipment or accessories is included under other sections of these specifications.

(e) Do not paint over any code-required labels, such as Underwriter’s Laboratories and Factory Mutual, or any other equipment identification, performance rating name, or nomenclature plates.

3.9.2 Quality Assurance

(a) Codes and Standards: Work and materials shall conform to regulations of Fire Department, safety color coding in conformance with OSHA and all other regulatory ordinances having jurisdiction. Conform to the most stringent requirements and authorities having jurisdiction.

(b)Single Source Responsibility: Provide primers and other undercoat paint produces by same manufacturer as finish coats. Use only thinners approved by paint manufacturer, and use only within recommended limits.

(c) Coordination of Work: Review other sections of these specifications in which prime paints are to be provided to ensure compatibility of total coatings system for various substances. Upon request from other trades, furnish information or characteristics of finish materials provided for use, to ensure compatible prime coats are used.

3.9.3 Submittals

(a) Product Data: Submit manufacturer's technical information including paint label analysis and application instructions for each material proposed for use.

(b) Samples: Prior to beginning work, Architect will furnish color chips for surfaces to be painted. Use representative colors when preparing samples for review. Submit samples for Architect's review of color and texture only. Provide a listing of material and application for each coat of each finish sample.

(1) On 300 mm x 300 mm hardboard, provide two samples of each color and material, with texture to simulate actual conditions. Resubmit samples as requested by Architect until acceptable sheen, color, texture is achieved.

(2) On actual wood surfaces, provide two 100 mm x 200 mm samples of natural and stained wood finish. Label and identify each as to location and application.

(3) On concrete masonry, provide two 100 mm square samples of masonry for each type of finish and color, defining filler, prime and finish coat.

(4) On actual wall surfaces and other exterior and interior building components, duplicate painted finishes of prepared samples. Provide full-coat finish samples on at least 9.2 square meter of surface, as directed, until required sheen, color and texture is obtained; simulate finished lighting conditions for review of in-place work.

3.9.4 Delivery and Storage

(a) Deliver materials to job site in original, new and unopened packages and containers bearing manufacturer's name and label, and following information:

Name or title of material

Manufacturer's stock number and date of manufacturer.

Manufacturer' s name

Contents by volume, for major pigment and vehicle constituents

Thinning instructions

Application instructions

Color name and number

(b) Store materials not in actual use in tightly covered containers. Maintain containers used in storage of paint in a clean condition, free of foreign materials and residue.

(c) Keep storage area neat and orderly. Remove oily rags and waste daily. Take all precautions to ensure that workmen and work areas are adequately protected from fire hazards and health hazards resulting from handling, mixing and application of paints.

3.9.5 Job Conditions

(a) Do not apply paint in rain, fog or mist, or when relative humidity exceeds 85 percent, or to damp or wet surfaces, unless otherwise permitted by paint manufacturer's printed instructions.

(1) Painting may be continued during inclement weather if areas and surfaces to be painted

are enclosed and within humidity limits specified and allowed by paint manufacturer during application and drying periods.

3.9.6 Products

1) Materials

(a) Material Quality: Provide best quality grade of various types of coatings as regularly manufactured by acceptable paint materials manufacturers. Materials not displaying manufacturer's identification as a standard, best-grade product will not be acceptable.

(1) Proprietary names used to designate colors or materials are not intended to imply that products of named manufacturers are required to exclusion of equivalent products of other manufacturers.

(b) Color Pigments: Pure, non-fading, applicable types to suit substrates and service indicated.

(1) All exterior colors and interior deep tone colors shall be ground in at the factory. Shop mixing is not permitted. Colors as selected by the architect, and subject to modification on the job at the Architect's discretion.

(2) content in pigment, if any, is limited to contain not more than 0.06 percent lead, as lead metal based on the total nonvolatile (dry-film) of paint by weight.

(3) This limitation is extended to interior surfaces and those exterior surfaces, such as stairs, decks, porches, railings, windows, and doors which are readily accessible to children under seven years of age.

2) Materials List

(a) Submit complete and detailed list with Painting Contractor's signature of the materials proposed for use on the work before ordering materials. Obtain Architect's approval before proceeding. Materials shall be the best quality of their respective kinds and suitable for the intended purpose, equal to or exceeding the following products, which are hereby set as standards.

(WP) Acrylic Emulsion water thinned coating, flat finish.

(EAE) Exterior Acrylic Enamel: A 100% acrylic latex water thinned coating with extra mildewcide, flat finish, conforming to Federal Spec. #TTP1SC, "Exterior Vinyl Bond Acrylic Masonry Paint" .

(ASE) Interior Acrylic Semi-Gloss Enamel: A vinyl acrylic water thinned, semi-gloss.

(AFE) Interior Acrylic Flat Enamel: 100% acrylic latex, water thinned washable flat finish.

(EP) Epoxy Paint: An epoxy polyester solvent thinned, two-component coating, semigloss finish.

(RIP) Rust Inhibitive Primer: An alkyd mineral spirit thinned, satin finish primer.

(BF) Block Filler: A vinyl acrylic latex, flat finish.

(PS) Primer Sealer: PVA vinyl acrylic water thinned, flat finish primer.

(ARE) Alkyd resin enamel: Industrial enamel.

(CS) Concrete Stain: A chemical stain in water solution.

(TMP) Traffic Marking Paint: Traffic and Zone Marking Paint.

(FR) Fire Resistance Paint: acrylic urethane finish coating shall be applied on two coats of Fire Resistance Paint on Red Lead Paint or recommended Primer by Supplier.

Supplier should submit approved Certification of Fire resistance Test granted from relevant Authorities.

3.9.7 Execution

1) Inspection

(a) Applicator must examine areas and conditions under which painting work is to be applied and notify Contractor in writing of conditions detrimental to proper and timely completion of work. Do not proceed with work until unsatisfactory conditions have been corrected in a manner acceptable to applicator.

(b) Starting of painting work will be construed as Applicator's acceptance of surfaces and conditions within any particular area. Do not paint over dirt, rust, scale, grease, moisture, scuffed surfaces, or conditions otherwise detrimental to formation of a durable paint film.

2) Surface Preparation

(a) General: Perform preparation and cleaning procedures in accordance with paint manufacturer's instructions and as herein specified, for each particular substrate condition.

(1) Provide barrier coats over incompatible primers or remove and reprime as required. Notify Architect in writing of any anticipated problems in using the specified coating systems with substrates primed by others.

(2) Remove hardware, hardware accessories, machined surfaces, plates, lighting fixtures, and similar items in place and not to be finish-painted, or provide surface-applied protection prior to surface preparation and painting operations. Remove, if necessary, for complete painting of items and adjacent surfaces. Following completion of painting of each space or area, reinstall removed items.

(3) Clean surfaces to be painted before applying paint or surface treatment. Remove oil and grease prior to mechanical cleaning. Program cleaning and painting so that contaminants from cleaning process will not fall onto wet, newly-painted surfaces.

(4) Cementitious Materials: Prepare cementitious surfaces of concrete, concrete block and cement plaster to be painted by removing efflorescence, chalk, dust, dirt, grease, oils, and by roughening as required to remove glaze.

(5) Determine alkalinity and moisture content of surfaces to be painted by performing appropriate tests. If surfaces are found to be sufficiently alkaline to cause blistering and burning of finish paint correct this condition before application of paint. Do not paint over surfaces where moisture content exceeds that permitted in manufacturer's printed directions.

(6) Clean concrete floor surfaces scheduled to be painted with a commercial solution of

muriatic acid, or other etching cleaner. Flush floor with clean water to neutralize acid, and allow to dry before painting.

(b) Wood: Clean wood surfaces to be painted of dirt, oil, or other foreign substances with scrapers, mineral spirits, and sandpaper, as required. Sandpaper smooth those finished surfaces exposed to view, and dust off. Scrape and clean small, dry, seasoned knots and apply a thin coat of white shellac or other recommended knot sealer, before application of priming coat. After priming, fill holes and imperfections in finish surfaces with putty or plastic wood-filler. Sandpaper smooth when dried.

(1) Prime, stain, or seal wood required to be job-painted immediately upon delivery to job. Prim edges, ends, faces, undersides, and backsides of such wood, including cabinets, counters, cases, panels.

(2) When transparent finish is required, use spar varnish for backpriming.

(3) Backprime paneling on interior partitions where masonry, plaster, or other wet wall construction occurs on backside.

(4) Seal tops, bottoms, and cut-outs of unprimed wood doors with a heavy coat of varnish or equivalent sealer immediately upon delivery to job.

(c) Ferrous Metals: Clean ferrous surfaces, which are not galvanized or shop-coated, of oil, grease, dirt, loose mill scale and other foreign substances by solvent or mechanical cleaning.

(1) Touch-up shop-applied prime coats wherever damaged or bare, where required by other sections of these specifications.

(2) Clean and touch-up with same type shop primer.

(d) Galvanized Surfaces: Clean free of oil and surface contaminants with non-petroleum based solvent.

3) Materials Preparation

(a) Mix and prepare painting materials in accordance with manufacturer’s directions.

(b) Maintain containers used in mixing and application of paint in a clean condition, free of foreign materials and residue.

(c) Stir materials before application to produce a mixture of uniform density, and stir as required during application. Do not stir surface film into material. Remove film, if necessary, and strain material before using.

4) Application

(a) General: Apply paint in accordance with manufacturer’s directions. Use applicators and techniques best suited for substrate and type of material being applied.

(1) Paint finishes are scheduled.

(2) Provide finish coats which are compatible with prime paints used.

(3) Apply additional coats when undercoats, stains or other conditions show through final coat of paint until paint film is of uniform finish, color and appearance. Give special attention to insure that surfaces, including edges, corners, crevices, welds, and exposed fasteners receive a dry film thickness equivalent to that of flat surfaces.

(4) Paint surfaces behind movable equipment and furniture same as similar exposed surfaces. Paint surfaces behind permanently-fixed equipment or furniture with prime coat only before final installation of equipment. Paint interior surfaces of ducts, where visible through registers or grilles, with a flat, non-specular black paint.

(5) Paint back sides of access panels, and removable or hinged covers to match exposed surfaces.

(6) Finish exterior doors on tops, bottoms and side edges same as exterior faces unless otherwise indicated.

(7) Sand lightly between each succeeding enamel or varnish coat.

(8) Omit first coat (primer) on metal surfaces which have been shop-primed and touch-up painted, unless otherwise indicated.

(b) Scheduling Painting: Apply first-coat material to surfaces that have been cleaned, pretreated or otherwise prepared for painting as soon as practicable after preparation and before subsequent surface deterioration.

(1) Allow sufficient time between successive coatings to permit proper drying. Do not recoat until paint has dried to where it feels firm, does not deform or feel sticky under moderate thumb pressure, and application of another coat of paint does not cause lifting or loss of adhesion of the undercoat.

(c) Minimum Coating Thickness: Apply materials at not less than manufacturer’s recommended spreading rate, to establish a total dry film thickness or, if not indicated, as recommended by coating manufacturer.

(d) Roof Flashing: Paint all exposed roof flashing that is not stainless steel.

(e) Mechanical and Electrical Work: Painting of mechanical and electrical work is limited to those items exposed in mechanical equipment rooms, in occupied spaces and equipment on roof.

(f) Mechanical items to be painted include, but are not limited to, the following:

Factory pre-painted diffusers at public spaces.

Piping, pipe hangers, and supports.

Heat exchangers.

Tanks.

Ductwork, insulation.

Sprinkler covers and pipes.

Motor, mechanical equipment, and supports.

Accessory items.

(g) Electrical items to be painted include, but are not limited to, the following:

Rooftop equipment.

Panel Boards in public spaces.

Conduit and fittings.

Speaker grilles.

Switchgear.

(h) Prime Coats: Apply prime coat of material which is required to be painted or finished, and which has not been prime coated by others.

(1) Recoat primed and sealed surfaces where there is evidence of suction spots or unsealed areas in first coat, to assure a finish coat with no burn-through or other defects due to insufficient sealing.

(i) Stipple Enamel Finish: Roll and redistribute paint to an even and fins texture. Leave no evidence of rolling such as laps, irregularity in texture, skid marks, or other surface imperfections.

(j) Pigmented (Opaque) Finishes: Completely cover to provide an opaque, smooth surface of uniform finish, color, appearance and coverage. Cloudiness, spotting, holidays, laps, brush marks, runs, sags, ropiness or other surface imperfections will not be acceptable.

(k) Transparent (Clear) Finishes: Use multiple coats to produce glass-smooth surface film of even luster. Provide a finish free of laps, cloudiness, color irregularity, runs, brush marks, orange peel, nail holes, or other surface imperfections.

(1) Provide satin finish for final coats, unless otherwise indicated.

(l) Completed Work: Match approved samples for color, texture and coverage. Remove, refinish or repaint work not in compliance with specified requirements.

3.9.8 Field Quality Control

(a) The right is reserved by Owner to invoke the following material testing procedure at any time, and any number of times during period of field painting:

(b) Engage services of an independent testing laboratory to sample paint being used. Samples of materials delivered to project site will be taken, identified and sealed, and certified in presence of Contractor.

(1) Testing laboratory will perform appropriate tests for any or all of following characteristics: Abrasion resistance, apparent reflectivity, flexibility, washability, absorption, accelerated weathering, dry opacity, accelerated yellowness, recoating, skinning, color retention, alkali resistance and quantitative materials analysis.

(c) If test results show that material being used does not comply with specified requirements, Contractor may be directed to stop painting work, and remove non-complying paint; pay for testing; repaint surfaces coated with rejected paint; remove rejected paint from previously painted surfaces if, upon repainting with specified paint, the two coatings are non-compatible.

1) Clean-up and Protection

(a) Clean-Up: During progress of work, remove from site discarded paint materials, rubbish, cans and rags at end of each workday.

(b) Upon completion of painting work, clean window glass and other paint-spattered surfaces. Remove spattered paint by proper methods of washing and scraping, using care not to scratch or damage finished surfaces.

(c) Protection: Protect work of other trades, whether to be painted or not, against damage by painting and finishing work. Correct any damage by cleaning, repairing or replacing, and repainting, as acceptable to Architect.

(d) Provide "Wet Paint" signs as required to protect newly-painted finishes. Remove temporary protective wrappings provided by others for protection of their work, after completion of painting operations.

(e) At completion of work of other trades, touch-up and restore all damaged or defaced painted surfaces.

3.9.9 Extra Stock

Deliver stock of maintenance material to the Owner's representative. Furnish maintenance material matching products installed, packaged with protective covering for storage and identified with appropriate labels.

Paint: Five (5) gallons of each of the paint colors.

3.9.10 Color Sections

Color Schedules: Colors and finishes and textures to be used shall be determined and directed by Architect. Color schedules will be furnished to the Contractor, well in advance of scheduled start of painting and finishing work.

3.9.11 Schedule of Paint Treatments

(a) General: Paint abbreviations refer to those noted previously in Part 2, Material List.

No. LOCATION	MATERIALS
1. Exterior & Interior Aluminum	Shop Coat: As specified in respective metal Ferrous Metal, Millspec section. Prime Coat: (RIP) Finish: Two coats (ARE)
2. Exterior & Interior Metal	Prime Coat: recommended Primer Finish: Two coats (ARE)
3. Factory Prefinished Metal	Finish: One coat (ARE)
4. Interior Exposed Smooth Concrete & Plaster where noted for water paint coating system. Including : Fascia, Soffits, Walls of Bldgs., Exposed Concrete Beams, Exposed Concrete Retaining Walls	Primer & Finish Coat: (WP) per manufacturer's recommendation
5. Exterior Plaster,& Concrete where noted for paint Including: Ceilings, Plaster Soffits and as indicated.	Prime Coat: (EAE) Finish: Two coats (EAE)
6. Interior Smooth Concrete & Gypsum Board Where	Scheduled. Prime Coat: (PS). Finish: Two coats (ASE or AFE).
7. Interior Masonry Where Scheduled.	Prime Coat: (BF). Finish: Two coats (ASE or APE).
8. Interior Smooth Concrete & Gypsum Board where	Prime Coat: (PS).

noted for epoxy.	Second Coat: (EP #371 Enamel). Finish: (EP #370 Clear Glaze).
9. Interior Masonry where noted for epoxy.	Prime Coat: (BF). Second Coat: (EP #371 Enamel). Finish: (EP #370 Clear Glaze).
10. Interior Wood for opaque finish.	Prime Coat: recommended primer Finish: Two coats Alkyd resin enamel (ARE)
11. Exterior/Interior Traffic Pavement Marking	One Coat Traffic Paint, minimum dry film thickness of 2.5 mils (.063 mm).
12. Interior Structural Steel Members Steel Beams and Girders Miner Steel Members	Prime Coat: Red Lead Paint Finish: as per Manufacture's Specification 1.5Hr Fire Resistance Paint: (FR) 0.5Hr Fire Resistance Paint: (FR)

4. MECHANICAL WORKS

4.1 GENERAL SPECIFICATIONS MECHANICAL WORKS

4.1.1 General

The Technical Specifications for the Mechanical Works detailed in generally refers to all machinery components, mechanical equipment, pump sets, control systems etc. These Tech. Specifications shall serve to specify all mechanical works wherever applicable within the scope of this Contract.

(a) Scope of Works

This Article covers the designing, manufacturing, testing before shipment, finishing, painting, packing, insuring, shipping and delivering to the site, erection, site testing, tests on completion and remedying defects of all the followings:

Pumping Station 1 :

Submersible pump (D200mm x 235.8㎥/hr x 7.7mH x 11kW)	: 2 sets
Butterfly Valve (D200mm)	: 2 ea.
Swing Check Valve (D200mm)	: 2 ea.
Dismantling Joint (D200mm)	: 2 ea.
Flap Valve (350mm)	: 1 ea.
Ultrasonic Flow Meter (D350mm)	: 1 ea.
PE coated Steel Pipe (D200mm, D350mm)	: 21m
HDPE Pipe (D400mm)	: 30m
Air valve, Drainage Pump, Fittings and accessories for piping works	: 1 L/S
Sluice Gate(1.2m x 1.2m)	: 1 ea.
Screen(1.8m x 3.0m)	: 1 ea.

Pumping Station 2 :

Submersible pump (D200mm x 277.2㎥/hr x 7.7mH x 11kW)	: 2 sets
Butterfly Valve (D200mm)	: 2 ea.
Swing Check Valve (D200mm)	: 2 ea.
Dismantling Joint (D200mm)	: 2 ea.
Flap Valve (350mm)	: 1 ea.
Ultrasonic Flow Meter (D350mm)	: 1 ea.
PE coated Steel Pipe (D200mm, D350mm)	: 21m
HDPE Pipe (D400mm)	: 100m
Air valve, Drainage Pump, Fittings and accessories for piping works	: 1 L/S
Sluice Gate(1.2m x 1.2m)	: 1 ea.
Screen(1.8m x 2.5m)	: 1 ea.

Main Canal, Secondary Canal, Tertiary :

Butterfly Valves, Flow Meters, Sluice Gates, Screens, etc.

At this project :

Maintenance equipment and tools : 2 sets

Spare parts : 2 sets

Miscellaneous metal works

The Works covered in this Article shall also include the supply and installation of all mechanical equipment associated with the foregoing scope of works. The Works shall also include the services of instruction to the project staff.

All shall be in accordance with these Specifications, the accompanying Drawings and in the Bill of Quantities.

All the costs and expense for the works which are not specified by the Item Numbers in the Bill of Quantities but required for the satisfactory completion of the Works provided in these Specifications, Drawings and Bill of Quantities shall be deemed to be included in the unit prices in the Bill of Quantities, and no separate payment shall be made for such works.

(1) Pumping station facility means pump, motor, valve and necessary parts and auxiliary facility.

(2) Performance and quality of all equipment shall be guaranteed by the responsibility of the Contractor.

(3) Manufacturers of all the equipment for the construction shall own full manufacturing facility and testing facility.

(4) Contractor shall submit all the documents related to the manufacturing facility and testing facility to the Engineer if requested by the Engineer.

(5) All the equipment in the design drawings presented shows approximate values of general size, shape and location. They are not expressing accurate values of any specific equipment.

(b) Requirement

The Contract shall:

(1) design (detail drawings of construction, manufacture drawings, etc.)

(2) manufacture

(3) test before shipment

(4) finish, paint and pack for export

(5) insure, ship, deliver to the port

(6) transport from the port to the site

(7) install, site test and remedy defects

All work shall be performed in strict accordance with the Technical Specifications, Drawings and Schedules.

The Plant shall be complete, with all parts in good working order, of good materials. Services not expressly called for in the Specifications or shown on the Drawings, but which are necessary for the complete and proper operation of the Plant, shall be performed and furnished by the Contractor at no extra cost to the Employer.

(c) Drawing and Documents to be Supplied by the Contractor

(1) Submission of Design Data

Before beginning to manufacture the equipment the Contractor shall submit, for approval, details of:

- design criteria and calculations
- pump performance curves
- calculation of hydrological strength of the gate
- dimensioned drawings and diagrams showing details of the equipment and materials to be used as well as arrangement related to other contractor's works.

All submissions shall be stamped "FOR APPROVAL", "DATE OF SUBMISSION" and the "CONTRACTOR'S SEAL".

Approval of the drawings will not exonerate the Contractor from any responsibility in connection under the Contract.

(2) Timetable for Approval

All submissions shall be made in sufficient time for the Engineer to make any necessary modifications without delaying the completion of the Works. The drawings and documents to be modified at the request of the Engineer shall be resubmitted for re-approval.

The Contractor's Construction Program shall allow at least eight weeks for such approval. Claims or extensions of time will not be permitted on account of the late submission of drawings and documents for approval, or for delays caused by drawings and documents being not approved by the Engineer.

All approved drawings and documents shall be submitted to the Engineer, stamped "FOR WORKS", "DATE OF APPROVAL" and the "CONTRACTORS SEAL", within two (2) months after receiving the approval letter.

The title of the drawings, the signature of the Contractor's responsible engineer, the date prepared, the drawing number, etc. shall appear in the bottom right-hand corner of the drawing.

The Contractor shall provide and submit, for approval, the specified number of drawings and documents within the time stated below:

	Number of Drawings		
Time for Submission	Required Information	For Approval	Approved

Within 90 days after signing the Contract	The detailed drawings related to mechanical works such as pumping station, valve, flow meter, gate, screen, etc. All drawings and documents for all equipment except the above mentioned ones	5	7

Further copies of particular drawings during the course of construction work are to be provided, if required.

(3) As-built Drawings

After all items of the Work have been manufactured and installed, the Contractor shall furnish to the Engineer As-built.

(d) Instruction of Project O&M Staff

During the period from commencement of installation work at the Site until five (5) months after the substantial completion of the Works, the Contractor shall instruct those employees designated by the Employer who will subsequently be responsible for the adjustment, operation, and maintenance of the Plant. The Contractor shall permit and facilitate the Employer's observation of the erection, installation, testing, etc., of the Plant. A proposed curriculum of instruction including on-the-job training shall be submitted, for approval, and be carried out to the satisfaction of the Employer and Engineer.

(e) Operating and Maintenance Manual

The Contractor shall submit, for approval, as early as possible, a draft Operations and Maintenance (O&M) Manual, with clear diagrammatic drawings of the equipment and flow charts to facilitate understanding of O&M procedure for all plant supplied. The Contractor shall, in preparing the O&M manual, take into account the lack of experience and familiarity of the operating personnel with this type of equipment.

The O&M Manual shall contain:

(1) Drawings which clearly show the correct manner of assembling, disassembling, operating and maintaining the Works, with special references to any recently developed features and shall furnish such approved instructions within three (3) months before acceptance of the equipment

(2) Use of main erection equipment and measurement devices

(3) Detailed procedures for assembling, adjusting, operating and dismantling of each component, system and machine

(4) Detailed procedures for maintenance of each component including the recommended frequency of inspections and lubrication

(5) A separate and complete section describing the normal operating procedures for the control of the pump motor unit and associated equipment

(6) A complete list of all drawings prepared for the Contract

(7) Lists of parts and spare parts for each item of equipment, including the manufacturer's code and serial numbers and ordering instructions. The parts list shall be detailed for only the equipment supplied and shall not include general reference or description of similar equipment which is of the same model but different in detail.

(8) Recommended periods between inspections and a trouble shooting guide for major equipment.

The O&M Manual shall be submitted for approval in the same manner as the drawings and when approved, ten (10) bound sets shall be furnished to the Engineer.

4.1.2 Standards

The Mechanical Works shall comply as a minimum with International Standards ISO, EN or BS Standards* named as I.S., with the respective Codes of Practice and Standards generally used for water supply and waste water facilities in foreign countries, adapted to the local conditions, shall be used as an alternative subject to written approval by the Engineer. For example:

BSCP:	British Standard Code of Practice
EN:	European Standard
BS:	British Standard
ASTM:	American society for testing materials
AWWA:	American Water Works Association
IEC:	International Electrical Commission
BSP:	British Standard Pipe (Thread)
CP:	British Standard Code of Practice
UK:	United Kingdom of Great Britain and Northern Ireland
ISO:	International Organization for Standardization
SI:	International System of Units

Other national or international or other authoritative standards equivalent or superior to those designated in the Specifications.

The Contractor shall demonstrate to the Engineer's satisfaction the equivalence or superiority of any item of Plant supplied to such alternative standards.

4.1.3 General Design Criteria

(a) General Nature of Specification

The Specification and Drawings show only the general type of equipment and the governing dimensions and are not intended to define the exact details of the equipment to be furnished. All equipment however shall comply with the general design criteria specified in this Clause.

The Contractor may submit, for approval, alternative details and arrangement based on his experience, provided always that such alterations require no major alteration to the civil and building works. The Drawings indicate the outline of the structure in which the equipment is to be installed. Any recesses required in this structure for alignment and grouting of embedded parts shall be determined by the Contractor.

The Contractor shall not make any changes to specified equipment or materials without prior written approval. Such changes shall not be detrimental to the interests of the Employer and shall not result in any increase in the Contract Price.

The Contractor shall be deemed to have examined the Specification and Drawings herewith and, unless stated specifically to the contrary in the Schedule of Departures from the Specification, to have concurred with the design and layout of the Works as being sufficient to ensure reliability and safety in operation, freedom from undue stresses, adequate drainage and other essentials for a satisfactory working Plant.

(b) Design to Resist Overstress

The design, dimensions and materials of all parts shall be such that, under the most adverse combination of stresses while are likely to occur during operation or maintenance, parts will not suffer damage, deflections or vibrations which might adversely affect the operation of the equipment.

Upon request of the Engineer, complete information regarding the design assumptions, loading and operating conditions, deflections and stresses used in the design shall be provided by the Contractor.

(c) Design to Resist Corrosion

Main parts which will have to be dismantled or which might have to be dismantled for purposes of servicing or replacement, shall be retained with anti corrosive fasteners.

Mechanisms shall be so constructed to avoid sticking due to corrosion.

(d) Design to Facilitate Maintenance

The design shall be such that the installation, replacement and general maintenance may be undertaken with the minimum of time and expense.

(e) Selection of Tolerances

Tolerances used for dimensions and finishes shall be selected with due consideration to the particular properties and functions of the parts and the corresponding accuracy required to obtain proper operation and tight sealing.

(f) Interchangeability of Parts

Wherever possible, all similar parts, including spare parts, shall be made to gauge and interchangeable. Such parts shall be of the same materials and workmanship and shall be constructed to such tolerances as to enable substitution or replacement from the spare parts to be made easily and quickly.

(g) Bases, Frames and Anchor Bolts

Suitable structural steel bases or frames shall be provided where necessary to transmit to the concrete foundations all loads imposed by the various parts of the equipment. Such bases or frames shall be supplied complete with suitable anchor bolts and shall be so proportioned that the bearing and shearing stresses imposed in the concrete foundations will not exceed 50 kgf/cm2 and 7.5 kgf/cm2 respectively.

(h) Resistance to Damage by Fire, Vermin, Dirt and Electricity

All Plant shall be designed to minimize the risk of fire and consequential damage, to prevent ingress of vermin, dust and dirt, and accidental contact with electrically energized or moving parts. The Plant shall be capable of continuous operation with minimum attention and maintenance in the exceptionally severe climatic conditions likely to occur in the Site.

4.1.4 Equipment Guarantee

The Contractor must ensure the Guarantee period of 2 years commencing from the date of successful take-over of the Plant. During the guarantee period, the Contractor shall maintain the equipment and carry out at least two overall inspections. During the guarantee period, in case of failure of any equipment or poor manufacturing, the Contractor shall be responsible for repairing and recovering smooth operation without delay, once he has been informed. If the Contractor fails to recover operation within 14 days, the Employer reserves the right to dispose by himself. The expenses shall be compensated by the Contractor with no rejection.

4.1.5 Design of Plant

(a) General

The names of the manufacturers of materials and equipment proposed for incorporation in the works together with procedures, performances, capacities, certified test reports and other significant information pertaining to the same, shall be furnished when requested for consideration by the Employer, who shall have power to reject any parts which, in his opinion are unsatisfactory or not in compliance with the Specification and such parts shall be replaced by the Contractor at no extra cost to the Employer.

The design, construction and layout of the plant and equipment shall be such as to ensure safety, simplicity and ease of operation, plus economy in maintenance. The plant shall be new, of sound workmanship and robust design.

All component parts shall be manufactured to a strict system of tolerances and complete interchangeability of similar parts is required. All wearing parts shall be readily available in Malawi. If not, they shall be listed in the tender as additional mandatory spares and sufficient spares for a period of two years priced within the schedules.

All warning signs, notices, other signs, labels and the like shall be provided by the Contractor.

(b) Materials

All materials utilized in the Plant shall be the most suitable for the duty concerned and shall be new and of first class commercial quality.

Particular attention shall be paid to material selection to minimize corrosion due to atmospheric conditions, contact with or submersion in corrosive liquids, electrolytic action of dissimilar metals, or any other causes which may reasonably be associated with the overall performance of the Works.

(c) Material Inspection and Testing

Materials, parts and assemblies thereof, to be incorporated into the Permanent Works shall be tested, unless otherwise directed, according to the best commercial method for the particular type and class of work. When the manufacturer desires to use stock material not manufactured specifically for the equipment furnished, satisfactory evidence that such material conforms to the requirements herein stated shall be furnished, in which case, tests on these materials may be waived. Certified mill test reports of plates and sections will be acceptable. In addition to the mechanical test required by the Specifications, all materials shall be examined in the shop for laminations and imperfections before incorporating them into the Works and any defective material shall be rejected.

(1) All castings should be flawless and without any repair and welding. For each castings, specimen shall be tested and a certificate to this effect shall be furnished by the manufacturer to the Engineer showing the conformity of the materials specified.

(2) The ultimate strength, limit of elasticity, ductility, hardness and other relevant properties shall be determined from such test pieces.

(3) The Contractor shall furnish, free of charge, all such test pieces cut and machined to the sizes, shapes and dimensions suitable for testing in accordance with the specified standards.

(4) The testing of the specimens shall be carried out by the Contractor at his own expense.

Four copies of all test reports and certified test reports giving the chemical analyses and physical properties of materials used shall be submitted for approval.

(d) Shop Assembly

All items of equipment shall be assembled in the shop before shipment and tests shall be performed by the Contractor as may be required to demonstrate, to the satisfaction of the Engineer, the adequacy of the equipment and its component parts. All tests shall simulate normal operating conditions as closely as possible.

All dismantled parts shall be properly matchmarked and dowelled to ensure correct assembly in the field

(e) Welding

Before starting the welding of pipe joints the Contractor shall submit for the Engineer’s approval details of the equipment, methods and materials he proposes to use, including make and size of electrodes, number of runs and current strength.

In all cases where welds are liable to be highly stressed before fabrication commences, the Contractor shall supply the Engineer with detailed drawings of all welds and weld preparations proposed. No such welding shall be carried out before the Engineer has signified his approval.

Welded components containing highly stressed fusion welds shall be stress relieved prior to machining. A smooth neat finish, by careful grinding if necessary is required on all exterior welding and shall be free from pitting or slag inclusions.

Radiographic examination or other non-destructive testing of welds may be ordered by the Engineer and the Engineer may witness such tests.

Other welds shall be subject to dye or magnetic particle penetrant testing.

Evidence of the valid certification of the welding personnel may be requested by the Engineer where necessary in accordance with BS 4872 or equivalent.

The technique of welding employed, the appearance and quality of the welds made and the methods used in correcting defective work, shall conform to the American Welding Society (AWS) Standard, or other approved equivalent standard.

(f) Nuts, Screws, Washers, Bolts and Anchors

Nuts, screws, washers and bolts shall comply with the relevant requirement of the following ISO standards unless otherwise specified:

(1) ISO 272

(2) ISO 885

(3) ISO 888

(4) ISO 4759

Bolting for pipes and fittings shall comply with ISO 7005/2 except that spheroidal graphite iron bolts for use with pipes and fittings shall be steel, galvanized to ISO 1459; ISO1460; ISO1461 or equivalent or sherardized to BS 4921 Class I or equivalent.

All bolts, nuts and washers which are liable to become submerged during the operation of the plant shall be nickel-chromium stainless steel. (Minimum quality 316 S13 to BS 970 or equivalent) All other threaded fixings, washers etc. shall be hot dipped galvanized to ISO1459, ISO1460 and ISO1461.

One washer shall be provided under each bolt head and nut. Bolt clearance holes shall be drilled, never flame cut.

(g) Special Tools

Any special tool provided for maintenance of the Plant shall be identified within the tender and supplied and handed over to the Employer on completion of the Works. Prior to handover the Employer and Contractor shall examine tools which have been used during plant erection to ensure that they are not damaged and are in good condition.

The recommended optional tools, including any special tools, gauges, jigs or extractors which may be required for maintenance of the Plant shall be set out in the appropriate schedule. A suitable lockable box shall be provided for each site to contain all tools provided.

(h) Lubrication

The initial changes of oils, greases, electrolyte and similar materials necessary for the correct setting to work and operation of the plant shall be included in the Contractor's price. All lubricants shall be readily available in Malawi

A complete schedule of recommended oils and other lubricants shall be furnished by the Contractor, for approval by the Employer. The number of different types of lubricants shall be kept to a minimum

When more than one special grease is required at a site a grease gun for each special type shall be supplied for that site and permanently labelled.

All lubrication systems shall be designed so as not to present a fire hazard and particular care shall be taken to prevent leakage of lubricant.

The Contractor shall supply flushing oil for each lubrication system when an item of plant is ready for preliminary running, and a sufficient quantity of the approved lubricants for setting to work for the operation of the plant for two years after issue of the Taking-Over Certificate.

(i) Vibration

Mechanical vibration levels at duty point conditions shall be in accordance with the requirements of ISO 2372 for range of vibration severity.

(j) Labelling

All labelling shall be in English. Each main and auxiliary item of Plant shall have permanently attached to it in a conspicuous position a rating plate of weather- resistant material. The Manufacturer's name, type and serial number of Plant, details of the loading and duty at which the item of Plant has been designed to operate shall be engraved on each plate. Where the Plant may have its rating plate in an inconvenient position (e.g. submersible pumps) then the Contractor shall supply an additional plate summarizing the particulars, which shall be fixed in a suitable location on the operating platform.

The labels shall be of non-corrode metal embossed with the lettering with black letters on white background and shall be fixed with brass or stainless steel screws. The labels shall be conspicuous and consistently located relative to the equipment to which they apply so that they can be read from the normal operating positions.

All safety signs shall comply with ISO 3864 or equivalent.

Plant which may start automatically shall carry labels (minimum size 200 mm x 100 mm) incorporating a hazard warning symbol and the following wording in black letters with yellow background:

(k) Color Coding For Water Supply

Pipes, valves, pumps etc. shall be color coded in accordance with below. The coding shall indicate the contents of the pipelines, purposes of the valves etc., and show whether or not the fluids being handled are dangerous.

Tape banding of pipes, of the appropriate color, shall be spaced at 3 m intervals and at every valve or junction, direction of flow arrows shall be provided together with process stream contents.

Stainless steel shall not have any paint system applied to its surface but imperfections and heat affected zones shall receive a suitable treatment to give a high quality uniform surface appearance.

COLOUR	BS 4800	CONTENTS OF PIPELINE
YELLOW LIGHT BROWN	10E53 08C35	Natural Gas Fuel Oil
LIGHT BLUE DARK BLUE	20E51 20D45	Compressed Air Instrument Compressed Air Process
DARK GREEN	14C39	Raw Water.

OLIVE GREEN LIGHT GREEN+	12D45 14E51±	Partially treated water Potable Water
DARK BROWN BLACK	06C39 00E53	Filter wash water etc. Consolidated Sludge
RED GREY	04E53 8I325	Casings, Flues etc. Motors, Gearboxes, Transmissions Structural Steel, Frameworks.

(l) Protection & Packaging

(1) Cleaning and Protection at Place of Manufacture

• Parts shall be cleaned prior to testing at the Manufacturer's Works. Parts subject to hydraulic test shall be tested before any surface treatment. After testing all surfaces shall be thoroughly cleaned and dried out prior to surface treatment.

• Bright parts and bearing surfaces shall be thoroughly polished and protected from corrosion by the application of rust preventative lacquer or high melting point grease before the parts are packed. A sufficient quantity of the correct solvent for removal of the protective compounds shall be supplied and packed with each particular part.

(2) Protection. Packing and Transportation

• Prior to dispatch from the Contractor or Manufacturer's premises all Plant shall be adequately protected by painting or by other approved means for the whole period of transit storage and erection, against corrosion and incidental damage.

• The flanges of the pipes, valves and fittings shall be protected by wooden discs attached by means of service bolts (which shall not be used at Site) or by other approved means. The sleeves and flanges of flexible couplings shall be securely tied. Cases containing rubber rings, bolts and other small items shall not normally weigh more than 50 kg gross.

• All items of Plant shall be clearly marked for identification against the packing list.

• All crates, packages etc., shall be clearly marked with a waterproof material to show the weight and where the slings should be attached and shall also have an indelible identification mark relating them to the packing lists.

(m) Embedded Metal work, Openings, etc.

(1) Unless otherwise specified, any foundations, wall and roof openings and coverings, concrete floor filling, sleeves in the foundations and walls, and trenches with floor plates for cables and pipes shall be provided by the Contractor.

(2) The Contractor shall supply and install anchors, fasteners, embedded metalwork, piping, conduit and sleeves associated with and required for the equipment being provided and installed under this Contract, unless otherwise specified.

(3) The Contractor shall show the location and full details of foundations, openings, trenches,

block outs and all embedded components on his drawings and shall be responsible for the completeness and accuracy of his drawings and the information which are to be supplied to others. Anchorages to be embedded in primary concrete will be installed by the Contractor in accordance with the Contractor's drawings. The Contractor shall be responsible for the adequacy and accuracy of location of all embedded components.

(4) All adjustments to foundation levels, embedment, bedding and grouting of the equipment on foundations and cementing into walls and floors shall be carried out by the Contractor. All levelling and adjusting of the equipment on foundations shall also be carried out by the Contractor.

(5) The foundation bolts, embedded steel parts, anchors, braces, posts, supports, shims etc. and all steel work as may be required for temporary or final support of anchorage of the equipment shall be provided and installed by the Contractor as part of this Contract.

(6) Any steel work which is to be built into the concrete foundations shall not be painted or coated unless otherwise approved.

4.1.6 Installation and Test

Installation by the Contractor shall include all necessary work required for performing the Contract, whether it is stated or not mentioned in the Contract.

(a) Test Procedure Instructions

The Contractor shall submit, for approval, during or immediately following the presentation of drawings, inspection and test procedures describing each test to be performed during manufacture, erection and tests on completion at the manufacturer's shop and the Site. The procedure shall define the sequence of inspection and tests, equipment preparation and operation procedures to be followed and the detail procedure for conducting the inspection and tests. These instructions shall be distributed in the same manner as the drawings.

(b) Tests at the Manufacturer's Shop

Tests at the manufacturer's shop shall be in accordance with Specification. All test reports shall be submitted to the Engineer.

(1) The Engineer will attend the shop assembly test for the pumps at the manufacturer's shop.

(2) The Contractor shall give notice at least 30 days in advance to the Engineer of the proposed commencement of the above witness test.

(3) If, for any reason, the Employer decides not to send a representative of the Engineer for the specified inspections, such inspections will be performed and conducted by an approved International Inspecting Agency.

(c) Tests on Completion

(1) During construction and after the installation of each item of equipment, control device, piping system, etc., tests shall be performed as specified and in accordance with approved test procedures, to establish the accuracy of the assembly and to prove the adequacy of the materials and the workmanship. Results of all tests shall be submitted for approval.

(2) The Contractor shall perform the following Tests on Completion, as applicable, to ensure

that the equipment has been correctly installed, all necessary adjustments and setting have been made, and the equipment is capable of operating under the design loads.

• Insulation tests of the equipment

• Testing and setting up of all relays

• Operation test of auxiliary equipment

• Pump alignment or mechanical test run

• Operation test of the equipment

• Any additional tests required by the Engineer to ensure the safety of the equipment

(3) The Contractor shall give the Engineer written notice of the date of the above tests not less than 21 days in advance. The Contractor shall conduct the operation tests in the presence of the Engineer to demonstrate that the entire work is properly installed, is free from objectionable leakage and is correctly adjusted to operate as specified. All the tests shall be carried out by the Contractor at his own responsibility and costs including necessary testing equipment and instruments, if any. Required electric power for the test shall be supplied by the Contractor without extra charge. Any defect observed during the tests shall be corrected by the Contractor and retested until it complies with the Specification.

(4) The Contractor shall be responsible for all routine maintenance, i.e., lubricating, inspection and adjustment of all equipment supplied under the Contract, until the conclusion of the tests on completion and the issuance of the Acceptance Certificate.

(d) Test and Inspection Reports

Unless otherwise specified, the Contractor shall submit, for approval, results of all test or inspections, including calculation sheets and photographs in the following manner.

Place of Test or Inspection	Number of Reports	Submission Time
Manufacturer's Shop	5	Before shipment
Site	5	Within 20 days after the test

4.2 DETAILED SPECIFICATIONS MECHANICAL EQUIPMENT

4.2.1 Submersible Pumps

(a) Design Conditions

< Pumping Station1 >

(1) Discharge: 2 pumps each of 235.8m^3/hr capacity shall provide a total discharge capacity of 471.6m^3/hr

(2) Water Levels and Heads : The suction and discharge water levels for the pumps are as follows.

Discharge Water Level	Suction Water Level	
H.W.L	L.W.L.	H.W.L.
EL.(+)136.30	EL.(+)130.49	EL.(+)132.69

(3) The design total head of the pumps shall not be less than the total head of 7.7m. The Contractor shall calculate the head losses of each pump from suction inlet to the end of the discharge culvert.

< Pumping Station2 >

(1) Discharge: 2 pumps each of 277.2m^3/hr capacity shall provide a total discharge capacity of 554.4m^3/hr

(2) Water Levels and Heads : The suction and discharge water levels for the pumps are as follows.

Discharge Water Level	Suction Water Level

H.W.L	L.W.L.	H.W.L.
EL.(+)127.80	EL.(+)123.79	EL.(+)125.59

(3) The design total head: of the pumps shall not be less than the total head of 7.7m. The Contractor shall calculate the head losses of each pump from suction inlet to the end of the discharge culvert.

(b) Detailed Specification of Pumps

Item	Specification		Remarks
	PS1	PS2	
Type	Submersible motor Pump	Submersible motor Pump	
Bore (Dmm)	200	200	
No. of Pumps(ea.)	2	2	
Discharge Quantity (m^3/hr)	235.8	277.2	
Actual Head (m)	5.81	5.01	
Total Head (m)	7.70	7.70	
Motor(kW x poles)	11kW x 6P	11kW x 6P	
Efficiency (%)	55.0	55.0	

(c) Material of Major Part

Submersible pumps shall suit the duty or capacity specified in the Bid Drawings The pump shall be direct driven by a close-coupled electric motor.

Pumps and drives shall be rated for continuous duty and shall be capable of pumping the specified flow range without surging, cavitation, or vibration.

The pumps shall not overload the motors for any point on the maximum speed pump performance characteristic curve within the limits of stable pump operation as recommended by the manufacturer to prevent surging, cavitation, and vibration, as well as throughout the entire pump operating range.

The mass of the unit and its distribution shall be such that resonance at normal operating speeds is avoided.

All parts of each pump shall be designed to withstand the stresses that will be imposed upon them during their handling, shipping, erection, and operation.

All units shall be so constructed that dismantling and repairing can be accomplished without difficulty.

(1) Casing

The casing shall be of close-grained cast iron to the requirements of ASTM A48 Class 40 designed for maximum heat transfer to the surrounding liquid. The casing shall be fitted with renewable wear rings

(2) Impeller

The impeller shall be constructed of close-grained cast iron, ASTM A48, Class 30 or better to the manufacturer's standard grade, preferably secured to the 316 stainless shaft by keying. The pump shall be provided with a separate, removable suction plate constructed of the same material as the casing.

(3) Shaft

Shaft seals shall be doubled and selected for a long service life. The choice of face material shall be suitable for the pumped media and to the recommendation of the seal manufacturer. However, it is envisaged that as a minimum the inner mechanical seal shall be constructed with a solid block carbon rotating seal face and a solid block silicon carbide stationary seal face.

(4) Fasteners

The pump-set shall be fitted with a stainless steel lifting handle designed for simple, safe and speedy removal of the pump-set using a permanently installed stainless steel lifting chain and shackle. Eyebolts shall be stainless steel. It shall be provided with stainless steel built in strainer.

(5) Motor

Motor housing shall be cast iron and hermetically sealed, squirrel cage induction type in oil filled chamber. Power shall be 400V, three phase, 50 Hz.

Motor and pump shaft to be integral, and provide waterproof, oil resistant, grounded, flexible power cord. Motor shall non-overloading throughout entire pump curve.

Capable of running dry for extended periods without damage to motor or seal

Provide motor of totally submersible design, enclosure IP 68 or equivalent.

(6) Motor lead cable

Conductors shall be copper stranded wire. Jacket shall be Vinyl or neoprene. Terminal head grommet shall be Epoxy sealed Buna - N.

(7) Automatic Discharge connector (with guide rail, lifting device)

The guide rail system design shall be such that the pump will be automatically connected to the discharge piping when lowered into place on the discharge connection. The pump must be easily removable for inspection or service, it must not be necessary to remove bolts, nuts or other fasteners, and it must not require the operator to enter the wet well.

Intermediate guide brackets are recommended for rail lengths over 6meter. Guide rails are part of the pump package and shall be supplied by pump supplier.

The discharge connector shall be manufactured of cast iron, ASTM A48 Class 30. It shall be designed to adequately support the guide rails, discharge piping, and pumping unit under both static and dynamic loading conditions with support legs that are suitable for anchoring it to the wet well floor.

The face of the inlet discharge connector flange shall be perpendicular to the floor of the wet well.

The pump design shall include an integral self-aligning sliding bracket.

The entire weight of the pump unit shall be guided to and wedged tightly against the inlet flange of the discharge connector, making metal to metal contact with the pump discharge forming a seal without the use of bolts, gaskets or O-rings.

Lifting chains, either galvanized or stainless steel, is suitable for removing and installing the pump unit.

(8) Pump protection sensor

It should be connected to various safety devices built into the submersible pump to protect the pump as follows.

- motor temperature sensor
- bearing temperature sensor
- leak detection sensor

(9) Monitoring Unit

It should be connected to the protection sensor to perform an alarm function when an abnormality occurs, and it consists of the following 3 channels to perform the protection function of each part separately.

① Channel A (Motor stator temperature)

One winding temperature sensing device per each is installed on the motor stator winding, and the contact point is operated at the specified temperature and the alarm function is activated. do.

② Channel B (Leak proof)

When an alarm occurs in the sensor due to water leakage, the alarm function is activated in channel B, and the general alarm function must be activated at the same time. After recovery to the normal state, it must be manually reset.

③ Channel C (Bearing temperature)

When the arbitrarily prescribed value is reached, the alarm function is activated immediately, and the general alarm function must be operated at the same time. After recovery to the normal state, it must be manually reset. In general, the alarm regulation value at 100˚C is set, but it should be able to change the setting value if necessary. It should be equipped with a terminal that can read the bearing temperature by attaching a digital meter.

④ Action (Go) channel (Inter Lock function)

When the alarm function is activated in the above 3 channels, there must be a contact point so that the pump can be set up by performing the interlock function.

⑤ Run channel

Since there is an alarm from the sensor even when the pump is not running, it must be possible to control by placing a Run channel to receive an alarm signal from the sensor during normal operation, and the Run function must be able to be performed by connecting to the outside. do.

⑥ Channel (comprehensive alarm)

When an alarm occurs in each channel, it must have the function of a comprehensive alarm that operates at the same time, and must be manually reset after recovery of the normal state.

(e) Testing and Commissioning & Training

(1) The Contractor shall be responsible for Erection, Testing & commissioning of complete submersible pump motor system, make all adjustment necessary to place the system in trouble-free operation.

(2) Pumps shall be run and a determination made of the pumping capacity. Performance of the pumps shall meet the specified criteria.

(3) Recorded readings shall be made of voltage and amperage on all electrical components at start and operating condition. Such readings shall be recorded on a form provided by the manufacturer and the results shall meet the manufacturer's prescribed limits. If a tested item fails to meet its requirements, then if shall be replaced.

(4) The Contractor shall be responsible for training the personnel to operate and maintain the submersible pump motor set with the manual.

4.2.2 Valves and Actuators

(a) General

Valves shall be suitable for use with water or water works sludge at all temperatures of up to 50°C and at high humidity.

All valves shall have following marking and they shall be designed cast in raised letters upon some appropriate part of the body.

- Name and mark of manufacturer
- Year of manufacturing
- Working pressure, NP10 (means 0.98 MPa)
- Arrow direction for valves designed for one-way flow only

Valve ends shall be flanged ends except where otherwise specifically specified elsewhere. Where flanged ends are used, mating dimensions and drilling shall be in accordance with the flange specified in Clause "4.2.3 (g)" Flanged Joints.

Thickness of flanges shall conform to internationally accepted standards, or the Contractor shall determine the flange thickness and shall submit his design calculation.

All materials which will be specified hereunder shall conform to ASTM, BS, or other internationally accepted standards.

Valves shall be equipped with hand lever, hand wheels, chain or hand, pneumatic or electric operators. Unless otherwise specified, manual operation valves shall have hand wheels. Valves shall open by turning to the left or counter clockwise. Operators shall have arrows cast thereon to indicate the direction of rotation for opening the valve.

All pipe connection openings shall be capped to prevent the entry of foreign matter prior to installation.

(b) Valves

(1) General

Valves shall be suitable for their application and media being passed and installed in such a manner as to allow ease of operation and maintenance.

The use of dissimilar metals in conjunction in a corrosive environment shall not be permitted, e.g. steel pipes and non-ferrous valves.

Valve gearboxes shall be provided where necessary to allow handwheel operation at maximum differential pressure. Gearboxes are to be fully enclosed.

All valves shall be capable of drip-tight isolation of the free end of an unsupported pipe and be capable of manual operation under maximum head conditions.

Valves up to 50 mm inclusive shall have screwed socket-welded or flanged ends according to service conditions and pipework layout.

Valves larger than 50 mm shall have flanged ends unless otherwise specified.

All gate valves shall be fitted with hand wheels unless otherwise specified. Stem caps shall be provided on all valves detailed for key operation and shall be secured with socket headed set screws.

(2) Testing

• General

The manufacturer shall notify the Engineer at least thirty working days prior to factory tests. The Engineer reserves the right to witness all tests.

• Performance Tests

Each valve, gate and appurtenance shall be shop-operated three times from the fully closed to the fully opened position, and the reserve, under a no-flow condition, to demonstrate that the complete assembly is workable.

• Leakage Tests

Valves, gates and appurtenances shall be shop-tested for leaks in the closed position. With the valve in the closed position, hydrostatic pressure as directed by the Engineer shall be supplied to one face of the disc for the full test duration at the working pressure. The length of test shall be at least 5 minutes and there shall be no indication of leakage past the valve during the test period.

• Hydrostatic Tests

Valves specified shall be hydrostatically tested. Hydrostatic tests shall conform to the following:

With the valve disc in a slightly open position, internal hydrostatic pressure equivalent to 150% of the specified working pressure shall be applied to the inside of the valve body of each valve for a period of 10 minutes. During the hydrostatic test, there shall be no leakage through the metal, the end joints, or the valve shaft seal; nor shall any part be permanently deformed. While undergoing testing, the valve body shall be struck with a hammer several times.

• Field Testing

When the valves, gates and appurtenances have been completely installed and as soon as operation conditions permit, they shall be given a field test by the Engineer to demonstrate that they have been suitably installed, that they meet all requirements, are in good operating condition and are, in every way, adequate for the service intended.

(3) Painting

All valves, gates and appurtenances, unless otherwise specified, shall have an interior ferrous port, except finish or bearing surface, painted with two (2) coats of epoxy paint or coal tar epoxy paint having total minimum dry film thickness of 0.4 mm. Material of the said epoxy paint or coal tar epoxy paint shall conform to AWWA C210 or shall be certified by the recognized public health authorities for linings in potable water service.

(4) Gate Valves

• General

The following Gate valves shall be specified hereinafter:

Gate Valves, Normal Pressure Service, NP 10 (50 mm to 500 mm)

• Reference

The following standards are referred to:

BS 5163	Sluice Valves for Waterworks
ASTM B 584	Bronze Casting
AWWA B115 10kgf/cm2	Sluice Valves for Waterworks
AWWA B120	Resilient Seated Gate Valves for Waterworks
AWWA C210	Liquid Epoxy Coating System for the Interior and Exterior of Steel Water Pipelines
AWWA C213	Fusion-bonded Epoxy Coating for the Interior and Exterior of Steel Water Pipelines
AWWA C500	Gate Valves, 3 through 48 in. NPS, for Water and Sewage Systems
AWWA C509	Resilient-seated Gate Valves, 3 through 12 NPS, for Water and Sewage Systems
BS 5163	Metric Specification for General Purpose Cast Iron Wedge Gate Valves.

• Gate Valves, Normal Pressure Service, Class NP 10 (50 mm to 500mm)

Gate valves, normal pressure service, working pressure of 0.98 MPa shall be pipe body, bronze-mounted, non-rising stem (NRS) type gate valves and shall be designed and manufactured in accordance with AWW C500, BS 5163 or AWWA B115 and in addition shall conform to the following requirement:
Stem shall be of cast, forged or rolled bronze or copper alloy or martensitic series stainless steel. Stem sealing shall be of stuffing box or O-ring type. Packing for the stuffing box shall be made of nylon. Asbestos or hemp of jute packing materials shall not be used. O-ring stem seals shall have a minimum of two (2) “O” ring seals, of which at least one (1) shall be above the stem collar and replaceable under full working pressure while the valves is in fully open position.

(5) Butterfly Valves

• General

The following butterfly valves shall be specified hereinafter:

Butterfly Valves, Class NP 10

All valves shall be equipped with electric actuators with hand wheels unless otherwise specified.

• References

The following standards are referred to:

BS 1452	Gray Iron Casting
BS EN 1563	Spheroidal Graphite Iron Casting
AWWA C504	Rubber-seated Butterfly Valves
BS 5155	Butterfly Valves

ISO 5752	Metal Valves for use in flanged pipe sy
s – face to	face and center-to-face dimensions

• Butterfly Valves - Class NP 10

Valves shall be double flanged, pipe body, rubber- seated butterfly valves, and shall be designed and manufactured basically in accordance with AWWA C504 or BS 5155 and in addition shall conform to the following requirements.

Valves shall be designed to be leak tight in both directions at a maximum working pressure of 0.98 MPa and at a maximum differential pressure of 0.98 MPa across the valve disc, and shall be suitable for a maximum velocity of 4.8 m/sec and for throttling service.

Each shaft shall be a one-piece unit extending completely through the valve disc, or of the "stub shaft" type, which comprises two separate shafts inserted into the valve disc hubs. If of "stub" construction, each stub shaft shall be inserted into the valve disc hubs for a distance of at least 1.5 times the shaft diameter.

Materials of shaft shall be either austenite series stainless steel, Type 304 or 316, or high yield strength martensitic series stainless steel.

If high yield strength martensitic series stainless steel such as Type 403, 420, 431 and others are used for the valve shaft, allowable torsional shear stress, not exceeding 25% of yield strength of the material used, shall be applied for design of valve shaft diameter.

Valve discs shall be made of stainless steel casting and shall be of design with no external ribs transverse to the flow. The design of disc shall withstand full differential pressure across the closed valve disc without exceeding a working stress, equivalent to 20% of tensile strength of the material used.

Rubber seats shall be applied to either the body or the disc, shall be of synthetic rubber, and may be reinforced. Rubber seats of valve 700 mm in diameter and larger shall be of a design that permits removal and replacement at the site of the installation. Rubber seats shall be clamped, mechanically secured, or bonded to the body or disc. Rubber seats shall mate with stainless steel seating surface. Clamps and retaining rings for rubber seats shall be made of stainless steel and hardware used with clamps and retaining rings shall be stainless steel.

Valves shall be fitted with sleeve type bearings contained in the hub of the valve body. Valves, 350 mm in diameter and larger shall be equipped with either one or two thrust bearings, which shall hold the valve disc securely in the center of the valve. Sleeve and other bearings fitted into the valve body proper shall be made of self-lubricated materials that do not have a harmful effect on potable water or rubber.

A shaft seal shall be provided where shafts project through the valve bodies for actuator connection. Shaft seals shall be designed for the use standard V-type packing; O-ring seals; O-ring-loaded, U-cup seals; or a pull-down packing. If O- rings are used, they shall be contained in a stainless steel or bronze removable recesses. If stuffing box and pull-down packing gland are used, the design of the valve and stuffing box assembly shall permit adjustment or complete replacement of packing without disturbing any part of the valve or actuator assembly except packing gland follower.

Gland or gland assemblies shall be made of stainless steel or bronze. Packing shall be made of resilient, non-metallic material suitable for potable-water service which shall not contain asbestos.

(6) Check Valves

• General

The following check valves shall be specified hereinafter:

Swing Check Valves (50 mm to 600 mm)

• References

The following standards are referred to:

BS 5150	Cast Iron Gate Valves
ASTM B 584	Bronze Castings
API 594	Wafer Check Valves
AWWA C508	Swing-Check Valves for Waterworks service, 2 in. (50.8 mm) through 24 in. (609.6 mm) NPS.

• Swing Check Valves (50 mm to 600 mm)

Swing check valves shall be cast iron body and disc, and bronze seating type. The valves shall be designed and manufactured in accordance with AWWA C508. Working pressure shall be 0.98 MPa.

Valves shall be suitable to operate in a horizontal or vertical position with flow

upward and when fully open, valves shall have a net-flow area not less than the area of a circle with a diameter equal to the nominal pipe size.

Valves shall be furnished with hinge arms, levers and springs or weights and also furnished with a by-pass pipe and by-pass valve.

(c) Valve Operators

(1) General

Operators shall be capable of seating, unseating and rigidly holding the valve disc in any intermediate position under the maximum design unbalanced head and water velocity noted.

Means for holding the valves in intermediate positions shall be furnished.

The operating mechanism of butterfly valve, plug valve and ball valve operators shall incorporate worm gears of bronze and worms of hardened steel operating in a lubricating bath totally enclosed in a sealed water tight gear case.

All valves shall be equipped with adjustable mechanical stop-limiting devises to prevent over travel of the valve disc in the open or closed position.

Operator housing, supports and connections to the valve shall be designed with a minimum safety factor of five (5) based on the ultimate strength, or three, based on the yield strength, of the material used.

Extension stem for valves shall be galvanized seamless steel pipe Schedule 80 with pinned coupling.

Support housing for extension stem shall be seamless steel pipe specified above, schedule 40 with reinforcing steel ribs if required.

Each rising-stem shall be provided with stem guard. The stem guard shall be galvanized seamless steel pipe specified above, Schedule 40. The guard shall be of sufficient diameter and length to permit full travel of the threaded stem without obstruction. Top of the guard shall be closed galvanized steel cap.

The stem guides shall be so constructed that when properly spaced they will hold the stem in alignment and yet allow it enough play to permit easy operation.

The guides shall be spaced in accordance with the manufacturer's recommendations for each stem size. The guides shall be adjustable with respect to the bracket to provide proper concentric alignment with the stem, and shall be so designed that alignment will be maintained after adjustment. Brackets shall be attached to the wall by sufficient anchor bolts to prevent twisting or sagging under load.

Each floor stand unit shall be provided with a position indicator to show the position of the valve disc at all times.

Manual operator shall require an input force of not greater than 178 N pull on either hand wheel or crank. Hand wheels shall be of cast iron, clearly marked with an arrow and the word "open" and "close" cast in relief on the rim. Hand wheel shall be of the spoke type only. Webbed or disc type shall not be used.

(2) Manual Valve Operators

• Manual Operators for Gate Valves

Manual operators for gate valves, 500 mm and smaller including resilient-seated gates, NRS type shall be wrench nuts and hand wheels type without gear ratio. OS&Y rising stem type resilient-seated gate valves shall be equipped with hand wheels without gear ratio. The wrench nut shall be 35 mm square at the base with taper 1 to 20 on each side to top of nut, and 63 mm high.

• Manual Operators for Butterfly Valve

Manual operators for butterfly valves shall be essentially an integral part of a butterfly valve. The rated torque capability of each operator shall be sufficient to seat, unseat, and rigidly hold in any intermediate position the valve disc it controls under the maximum operating condition.

All gears operators shall be self-locking and designed to transmit two (2) times the required operator torque without damage to the faces of the gear teeth. Each manual operator shall be equipped with a position indicator which shall read both in percent (0 – 100%) with minimum graduation of 5% and in degrees (0 – 90 degrees) with minimum graduation of 5 degrees. The graduation shall be engraved on operator cover plate.

• Gearing

Gears shall be of steel, or bronze, accurately machines with cut teeth, and smooth running with suitable shafts in bronze sleeve bearings or roller bearings of ample size.

All gears and bearings shall be enclosed in a cast-iron housing. Fittings shall be provided so that all gears and bearings can be periodically lubricated. For remotely operated valves, the operator shall be supplied with a cast-iron pedestal, machined and drilling to receive the gear housing and drilled for bolting to the operating floor.

(3) Electric Valve Operators

• General

Two (2) types of electric valve operators such as Type A, integral control type and Type B, standard type shall be specified hereinafter.

Each type electric valve operator shall be furnished in weather-proof construction. The motor shall operate on 400 volt, 3-phase, 50 Hertz, service for open-close and throttling service.

Each type electric valve, operator shall be mounted by the valve manufacturer, tested and adjusted prior to shipment. All electric valve operators shall be designed and manufactured in accordance with AWWA C540 and shall be Limitorque SMB type or other type approved by the Engineer.

Electric valve operator, Type A shall be integral control type and shall include, but not be limited to, the electric motor, reversing magnetic starter, limit switches, torque switches, space heaters, valve position potentiometer if specified, push-button station, shop wiring, gear case and a declutch hand wheel to allow manual operation of the valve.

The valve control units shall have pushbutton stations furnished in enclosures suitable for flush panel mounting or field mounting as required. The stations shall include pushbuttons, status lights, and a selector switch all as required.

Electric valve operator, Type B shall be standard type and include, but not be limited to, the electric motor, reversing magnetic starter, limit switches, torque switches, space heaters, valve position potentiometer if specified, shop wiring, gear case and a declutch hand wheel to allow manual operation of the valve.

• Electric Valve Operators for Butterfly Valve

Gear Case shall be of cast iron. Flanges for motor attachment and pedestal attachment shall be integrally cast, fully machine and template drilled.

Motors for electric valve operator shall be capable of producing not less than 1.5 times the required operator torque. Any gearing in direct association with the electric motor shall be totally enclosed and shall operate in a lubricant.

Operator shall include an adjustable torque or thrust-limited switch capable of stopping the power to the motor when the valve has reached the stops in the open or closed position or when an obstruction has been encountered in either direction of travel. Torque switches shall be factory set to satisfy the calculated value corresponding to the maximum operating conditions.

Limit switches shall be geared to the drive mechanism and in step at all times whether the unit is operated electrically or manually.

The switches shall be of the adjustable type capable of being set to trip at the fully open or fully closed valve positions or at any point between.

All electrical inter-connections between limit switches, torque switches, indicator lights, and so forth, shall be factory- wired and ready for operation.

All gearing used in connection with limit switches shall be factory-lubricated. Operator shall be provided with a position indicator to show the position of the valve at all times. The indicator shall read in percent (0 – 100%) with minimum graduation of 5%.

Operator shall be equipped with a handwheel for manual operation.

The hand wheel shall be connected so that operation of the motor will not cause the handwheel to rotate and the operation of the handwheel shall not cause the motor rotor to rotate.

The handwheel shall be engaged by an exterior lever or an automatic clutch. The action of the lever shall also declutch the motor if there is no device to accomplish this automatically when the power supply to the motor ceases.

Should the power return to the motor while the handwheel is in use, the design of the unit shall prevent the power from being transmitted to the handwheel.

An arrow and the word “open” and “close” shall be placed on the handwheel to indicate direction of resultant valve movement.

(d) Air Valve

(1) Material and structure

The main material and structure of the valve is a rapid air valve for water supply and should have the following characteristics.

• Material

The material of each part complies with AWWA C512 4.2.

• Structure, shape and dimensions

- The valve consists of a valve body, a float valve, a flow valve, and a cover, and has a structure with a large air hole and a small air hole.
- The large air hole has a large amount of exhaust function, and when the large amount of exhaust is finished, it is closed by the flow valve.
- The small air hole has an exhaust function during water supply and must be of a structure that is opened or closed by a float valve.
- The flow valve is installed on the upper part of the float valve, and the flow valve is operated by the buoyancy of the float valve.
- A cover should be installed on the upper part of the cover to prevent dust, etc. from entering.
- Rubber and synthetic resins used in valves should not adversely affect water quality.
- The flange size is in accordance with AWWA C512 4.3.

(2) Performance

• Rapid exhaust function: Large amount of exhaust*1) should be done quickly.

• Rapid intake function: Large amount of intake*2) must be achieved rapidly.

• Exhaust function under pressure: Exhaust under pressure*3) should be performed smoothly.

Note) *1) Large amount of exhaust is exhausted through the large air hole when the valve fills the pipe with water.

*2) Large amount of intake is intake through the large air hole when the valve excludes water in the pipe.

*3) Exhaust under pressure is when the valve automatically exhausts the air collected at a high place in the pipe through the small air hole during water supply.

(3) operation

• The function of air discharge and float valve should be good and its operation should be smooth.

• Air displacement(Q) must be greater than or equal to the following values.

Nominal Diameter(mm)	80	100	150	200
Minimum displacement by air valve differential pressure(ho) 0.05kgf/㎠[0.049bar]	11	19	43	76

• In case of large amount of exhaust, the float valve or flow valve must not be sucked up by the exhaust and blocked by the air hole until the differential pressure (ho) of the air valve reaches 0.1kgf/cm2[0.098bar].

• The valve should operate smoothly even if it is installed with an inclination within 2°

from the vertical.

(4) Inspection and testing

• Appearance and dimensional inspection

- Castings must have a smooth surface and no voids, cracks, cracks, blemishes, casting ears, or other defects harmful to use. However, for minor porosity, flaws, etc., it can be used after welding repair with the approval of the engineer, and the dimensional inspection shall be in accordance with the approved drawings.
- The painted surface shall have no unpainted parts, bubbles, swelling, peeling, adhesion of foreigns

• Testing

Testing is in accordance with AWWA C512 5.1.

4.2.3 Piping Works

(a) General

Each pipe, fitting and casting shall bear clear and durable markings showing the nominal diameter, class or schedule, type, year of manufacture and the manufacturer's name or trade mark. Marking on pipe lengths shall always be at the same end.

Pipes and fittings shall be compatible and have equal or higher pressure ratings as specified.

Pipes, fittings and appurtenances shall be installed in full conformance with the manufacturer's recommendations.

When cutting of pipe is required, the cutting shall be done by machine in a neat and workmanlike manner without damage to the pipe, coating or lining. Cut ends shall be smooth and at right angles to the axis of the pipe. Pipe ends to be used with rubber joints shall be beveled and filed or ground smoothly to conform to the manufactured spigot end.

The Contractor shall furnish and install transition pieces at all locations when one type of pipe joins a second one.

At the conclusion of the work the Contractor shall clean all piping and pipelines.

(b) Standards

Pipes and fittings shall comply with the relevant provisions of the appropriate ISO Standard or equivalent as set out below:

(1) Steel pipes, specials and fittings	BS 534, 3600, 3601, 1640, 1965
(2) Metal arc welding of steel pipes	BS 2971
(3) Screwed pipes & fittings for pressure	ISO49, BS1256. ISO65
(4) Purposes for water, air and oil	ISO445
(5) Copper pipes and fittings	ISO 2016, BS 2871
(6) Pipe Flanges	ISO 7005/2/3

(7) Rubber hoses for use with compressed air	ISO 2398
(8) Pipe supports of fabricated steel	BS 3974

Materials and coatings used shall be unconditionally resistant to the conveyed fluids.

(c) Pressure Rating

Pipework and fittings shall be suitable for a safe working pressure equivalent to the maximum working pressure of the system. The safe working pressure of pumping mains shall be the closed valve head of the pump plus the maximum suction static head. The pipework shall also be rated for the maximum surge pressures generated in the system.

(d) Design

All machinery stations shall be provided with flexible joints, flange adaptors or unions such that upon renewal of plant minimal disturbance of pipework is required.

The pipework system shall be so designed to ensure that anchorage at blank ends, bends, tees and valves may be kept to a minimum. The Contractor shall provide and install all anchor blocks and mechanical ties required to support and accommodate system thrust loadings unless otherwise stated.

There shall be a sufficient number of mechanical joints to enable mechanical plant and valves to be disconnected from built-in pipework. Such joints shall be tied, as required to counter hydraulic loadings and shall not be allowed to sustain the weight of any pipework.

Puddle flanges shall be provided on all pipes where they pass through pumping station walls. The Contractor shall provide and ensure a gas tight seal at the penetration.

Where pipes pass through a concrete wall or structure they shall, where space permits project from the external face(s) of the structure by 300 mm for pipes with nominal bores of 500 mm or less and by 500 mm for pipes with nominal bores in excess of 500 mm and the surface of such pipes shall be prepared to the approval of the Employer to ensure a satisfactory bond between pipes and concrete.

(e) Handling

Care shall be taken during loading, transporting, and unloading to prevent injury to the pipes, fittings, or coatings. Under no circumstances shall pipe or fittings be dropped or rolled against one another. All pipes or fittings shall be examined and no piece shall be installed which is found to be defective.

If any defective pipe or fitting is discovered after it has been installed, it shall be removed and replaced with a sound pipe in a satisfactory manner by the Contractor, at his own expense. All pipe and fittings shall be thoroughly cleaned before installation.

Special handling of pipes and fittings shall be in accordance with the manufacturer's instructions.

All pipes shall be bundled or packaged in such a manner as to provide adequate protection for the ends, threaded or plain, during transportation from the manufacturer to the Contractor.

(f) Inspection

The quality of all materials, the process of manufacture, and the finished piping shall be subject to inspection and approval by the Engineer by an independent testing laboratory selected by the Employer, or by other representatives of the Employer. Such inspection may be made at the place of manufacture or at the site after delivery, or at both places, and the pipe shall be subject to rejection at any time on account of failure to meet any of the specification requirements, even though sample pipes may have been accepted as satisfactory.

When any routine chemical analysis fails to meet the requirements of these specifications or when any specified test fails to meet the requirements, all pipe in the same sampling period shall be rejected, except that any pipe that is subsequently re- tested and is judged acceptable, may be accepted.

All pipes, and appurtenances will be inspected by the Engineer upon delivery to the site and those pieces, not conforming to the requirements of this specification, will be rejected and must be immediately removed from the site by the Contractor. The Contractor shall furnish all labor necessary to assist in inspecting the material.

On completing the installation, the inside of the pipe shall be carefully cleaned of tools, scrap, dirt and debris. The Engineer will make a full and complete inspection of all lines before acceptance and the Contractor shall fully flush out the lines with water and air prior to inspection.

(g) Flanged Joints

Flanged joints shall be furnished complete with gaskets, bolts and nuts.

Gaskets shall be cut to the proper size so that no part protrudes. Prior to application of gaskets, the face of the flanges shall be thoroughly cleaned.

All gaskets supplied with each flange fitting shall be styrene butadiene rubber conforming to BS 2494 or equivalent. Thickness of gasket shall be 3 mm.

Flange assembly bolts shall be standard hexagon head machine bolts with hexagon nuts. Threads shall conform to ISO 68, "ISO General Purpose Screw Threads-Basic Profile". Material for bolts and nuts shall be steel conforming to ASTM or BS or other internationally accepted standards, and shall have a minimum yield strength of not less than 226 N/mm^2. Steel bolts and nuts shall be galvanized. Bolts and nuts for intermittent or continuous underwater pipe work shall be Type 304 stainless steel.

Bolts and nuts for stainless steel flanges shall be stainless steel and type of stainless steel shall be the same as the flanges.

Bolts in flanged joints shall be tightened alternately on opposite ends of joints diameters, in rotation around the flange and evenly.

The bolts shall not protrude more than 3 mm beyond the nuts. Should the bolts protrude more than 3 mm, the bolt ends shall be machined cut and refinished.

Mating dimensions of flanges, nominal diameter 80 mm to 1,600 mm shall conform to dimensions shown on the following FLANGE SCHEDULE. Mating dimensions and thicknesses of flange, nominal diameter 65 mm and smaller shall conform to ISO, ANSI, or BS or internationally accepted standards and the working pressure of the flange shall be 0.98 MPa.

NOMINAL DIAMETER	O.D. of flange	Diameter of bolt circle	BOLT		
DN	D	C	NUMBER	d	
80	200	160	8	19	16
100	220	180	8	19	16
150	285	240	8	23	20
200	340	295	12	23	20
250	400 (405)	355	12	28	24
300	445 (460)	410	12	28	24
350	520	470	16	28	24
400	580	525	16	31	27
450	640	585	20	31	27
500	715	650	20	34	30
600	840	770	20	37	33
700	910	840	24	37	33
800	1025	950	24	40	36
900	1125	1050	28	40	36
1000	1255	1170	28	43	39
1100	1355	1270	32	43	39
1200	1485	1390	32	49	45
1400	1685	1590	36	49	45
1500	1820	1710	36	56	52
1600	1930	1820	40	56	52

- Definitions : DN - Nominal diameter of pipe
  D - O.D. of flange
  C - Diameter of bolt circle
  d - Diameter of bolt holes
  () - Only for steel flange
- Note: Bolt holes shall straddle the vertical center line of the flange.

(h) Steel Pipe

(1) General

All welding shall be in accordance with the welding under the provision unless otherwise specified.

(2) References

The following standards are referred to:

- BS 4622 Grey Iron Pipe Fittings
- BS 1965 Carbon Steel Pipe Fittings
- BS 4360 Rolled Steel for General Structure
- BS 1387 Carbon Steel Pipes for Ordinary Piping

• AWWA C200	Steel Water Pipe 6 Inches and Larger
• AWWA C206	Field Welding of Steel Water Pipe Joints
• AWWA C208	Dimensions for Steel Water Pipe Fittings
• AWWA C210	Liquid Epoxy Coating System for the Interior and Exterior Steel Water Pipe
• AWWA	Manual Steel Pipe Design and Installation M11
• ASTM A283	Low and intermediate Tensile Strength Carbon Steel Plates

(3) Pipes

Steel pipe shall be fabricated from steel sheets or plates and shall be arc welded or electric-resistance welded, shop fabricated, tested and cleaned.

Steel sheets or plates shall have a minimum yield point not less than 226N/mm^2 and shall conform to the following materials.

- BS 4360
- BS 1387
- ASTM A283 Grade D

Fabrication of steel pipe shall be in accordance with BS 1387 or AWWA 200. The weld shall be of reasonably uniform width and height for the entire length of the pipe and shall be made by automatic means except that with approval of the Engineer, manual welding by a qualified procedure and welder may be used.

All longitudinal seams or spiral seams and shop girth seams of pipe shall be butt welded. The maximum allowable number of shop seams shall be one longitudinal seam and three girth seams per length of pipe. The longitudinal seams shall be staggered on opposite sides for adjacent section. No reinforcing ring, plate or saddle shall be provided on the exterior or interior of pipe. The length of pipe shall be six (6) meters or smaller unless otherwise specified.

(i) Dismantling Joint

(1) General

All flexible joints and couplings shall be designed for a minimum working pressure of 0.98 MPa unless otherwise specified and to the maximum designed working pressure.

(2) References

The following standards are referred to:

• BS 4360	Rolled Steel for General Structure
• BS EN 1563	Spheroidal Graphite Iron Castings
• BS 2494	Elastomeric seals for joints in pipe work

(3) Materials and Structure

Compensates for axial displacement of the pipe during installation and dismantling, as the telescopic action between the inner and outer flange body allows for longitudinal adjustment

It is designed with three flanges connected with tie-rods, and where the center flange applies compression on the seal through the tie-rods

- Standard axial adjustment : ±40-80 mm
- Flange Drilling : ASME/ANSI B16.5/B16.47
- Fabricated Flange Adaptor :
  - Body - Rolled Steel to BS EN 10025-2: Grade S275
  - End Rings - Ductile Iron to BS EN1563: Symbol EN-GJS-450-10 or Rolled Steel to BS EN 10025-2: Grade S275
  - Sleeve - Steel Tube to BS EN10255: or Steel Tube to BS EN10216-1: Grade P265TR1 or Rolled Steel to BS EN 10025-2: Grade S275 or Rolled Steel to BS EN 10025-2: Grade S355 (depending on section)
- Flanged Spigot :
  - Flange - Rolled Steel to BS EN 10025-2: Grade S275
  - Spigot - Steel Tube to BS EN10255: or Steel Tube to BS EN10216-1: Grade P265TR1
- Gasket : BS EN681-1:1996 Type WA WRAS listed
- Steel Tie Rods & Nuts :
  - Tie Rods - BS EN10269: Name 42CrMo4 (Yield 725N/mm^2) (formerly B7)
  - Nuts - BS EN20898-2: Property Class 8.0

(j) Pipe Installation

(1) General

This section covers the installation of all pipe and fittings except all pipe and fittings in the ground.

- Piping shall be installed to the required lines and grades and as closely as possible to walls, ceilings, columns and other structural parts so as to occupy the minimum of space, and all offsets and fittings required to accomplish this must be furnished. All dimensioned pipes and fittings shall be installed before fitting make up pieces, and the whole shall be joined so that no stress or strain is created in the lines and associated equipment due to forcing parts into position.
- When installation is not in progress, including lunchtime, the open ends of the pipe shall be closed by a watertight plug or other approved means. Flotation of pipe shall be prevented. Good alignment shall be preserved during installation. In the event interference develops between piping and other appurtenances the Engineer will decide which work is to be relocated regardless of which was first installed.
- Changes in direction shall be made using proper fittings. Piping shall run parallel and at right angles to walls, unless noted otherwise.
- Temporary bracing and supports shall be provided to adequately support the pipe during its installation and care shall be taken in placing piping to prevent damage to the pipe lining or pipe coating or to adjacent structures or equipment. Supporting piers and blocking shall be in place before temporary supports and bracing are removed.
- All piping shall have a sufficient number of flanged joints to allow convenient removal of piping. Threaded piping shall have a sufficient number of unions to allow convenient removal of piping.

- Systems shall be arranged with low points and drains to permit complete drainage of the system

(2) References

The following standards are referred to:

- AWWA MANUAL
- M11 Steel pipe design and installation
- M23 PVC Pipe Design and Installation

(3) Steel pipe

- General

Steel pipe shall be installed in accordance with AWWA M11.

All work shall be in full conformance with the manufacturer's recommendations.

The lining and coating shall be protected at all times. All repairs shall be the responsibility of the Contractor.

Where steel pipe passes through wall sleeves, the sleeves shall be caulked with sealing compounds recommended by the pipe manufacturer and approved by the Engineer.

- Flanged Joints

Same as previous Clause "4.2.3 (g)" Flanged Joints.

- Screwed Joints

All threads for screw joints shall be clean, machine cut, and all pipes shall be reamed before erection. Each length of pipe as erected shall be up-ended and rapped to dislodge dirt and scale.

Screwed joints shall be made up with good quality thread compound and applied to the male thread only. After having been set up, a joint must not be backed off unless the joint is completely broken, the threads cleaned, and new compound applied. All joints shall be airtight.

- Welded Joints

Welding shall be in accordance with the Clause "4.1.5(e)" Welding.

- Flexible Joints

During transportation, handling, storing and installation, any deflection, contraction, expansion or any other transformation of the flexible joints shall be avoided. Extreme care must be made to prevent any scarring or nicking of the joints from bearing on sharp objects.

All flexible joints shall be installed true to the lines and levels and the Contractor shall maintain the joints in the same condition as shipped from the manufacturer. Disassembling the joints at the site shall be avoided unless otherwise directed by the Engineer. The Contractor shall not remove any protective ribs, shipping protection or other devices provided to the joints before jointing work is completed.

4.2.4 Flow Meter

(a) Ultrasonic Flow Meter

(1) Material

A flowmeter consists of a measuring part (measuring tube), a control calculation part, and a dedicated cable. In particular, the measuring part and sensor, which are parts that come into contact with the fluid, must be made of a material applicable to the fluid. The pressure transmission system consists of a pressure measuring part and a dedicated cable, and the panel must be made of an operation part and a function part.

• Measuring unit

The shape of the measuring part is composed of an ultrasonic detector and a measuring tube manufactured according to the environment in which it will be installed.

The measuring tube is a part that is in direct contact with the fluid and is subjected to pressure, and all parts that receive pressure from water pressure must be manufactured and processed with a material that is rated for the installation conditions. For flow pipe inner diameter, it is recommended that the inlet in the measurement direction has a deviation of less than 1% from the existing pipe.

The measuring pipe must be guaranteed and consistent with the maximum allowable operating pressure, measuring pipe material, flow direction indication (arrow), flow range and performance.

• Calculation unit

It includes a discharge, reception, and time measurement circuit configured to obtain 5 sets of measured flow rates in the calculation unit, a calculation unit that can calculate it, and a control calculation unit with a function to store and display it on the screen

. These circuits must be stored in a safe case.

The circuit must be designed and manufactured in a structure that can transmit and receive ultrasonic signals, measure the propagation time difference, calculate the real error and display use, it must tell whether the flow rate is (+) or (-), and since it comes with an analog output as well as a digital output, it must be manufactured and processed to know the state and direction of the output.

• Flow meter panel

The flow meter panel for pressure measurement protects the controller from the external environment and transmits the flow data to the central control room.

Depending on the site conditions, the flowmeter control and calculation unit may be attached to the RTU panel.

It must be equipped with a pressure gauge that can indicate pressure data and an indicator with an output divider function, and must be equipped with a double door lock and door lamp ON/OFF switch.

(2) Function

The indication part of the flow meter calculation unit should be able to read the indication amount of the passing fluid easily and clearly, and it should be reliable and clear. Therefore, the font size of the flow rate should be at least 4 mm.

- It can have additional functions to enable testing or calibration by the automated inspection facility of the flowmeter calculation unit.
- The indication of the quantity passed from the measurement time should be continuously displayed in ㎥ without interruption, and it can be expressed as a digital number that

changes immediately.

- The indicator device should be able to display the volume corresponding to 1600 hours at the maximum flow rate in ㎥ without going over to “0”, and the indication range of the flowmeter should be at least 7 digits.
- Main functions of flowmeter

- Screen display function : instantaneous flow rate, accumulated flow rate, water pressure, static electricity record, etc.
- I/O function : 4-20mA, Pulse, RS232C/485, Alarm. Relay
- Save and download function : Data stored such as instantaneous flow rate, accumulated flow rate, water pressure, static electricity record, etc. can be downloaded using serial communication or USB.
- Measurement unit: flow velocity m/s, instantaneous flow ㎥/s, /min, /h, /day, accumulated flow (㎥, L), pressure kgf/cm2, bar

(3) Performance

- Operating temperature: measuring part (-20 ~ +85℃), calculating part (-20 ~ +60℃)
- Allowable pressure: PN 10(bar), water pressure measurement range (0.1 ~ 20 bar)
- Protection class: IP68
- Flow rate range: -30m/s ~ +30m/s (0.01m/s)
- Precision : 0.5% ~ 1.5%

(4) inspection

- General method: The flow should be stable, and at the inlet of the upstream straight pipe, the flow should be axisymmetric and there should be no large pulsations or vortices. A reference flowmeter or calibration reference for flow rate or flow measurement must comply with international standards.

  The reference flowmeter or calibration standard must have a range that satisfies the flow range of the flowmeter under test, and the range of changes in pressure and temperature during the test must be changed within the rated operating conditions.

- Rated operating conditions: The rated operating conditions of the flowmeter are as follows.

  - Flow range: from minimum flow (Q1) to maximum flow (Q3)
  - Ambient temperature range: 0 % to 100 % (0 % to 93 % for remote indicator)
  - Water temperature range: from 0.3℃ to 30℃
  - Pressure range: from 0.03 MPa (0.3 bar) up to 1 MPa (10 bar)

- Standard conditions: Except for the test on the inflow of the flowmeter, all values should be maintained at the following values while the test is being performed.

  - Flow rate: zero point
  - Working temperature: 20±5 ℃, Ambient temperature: 20±5 ℃
  - Relative Humidity : 60±15 %
  - Atmospheric pressure: 86~106 kPa (0.86~1.06 bar)
  - Electric wave: rated voltage
  - Frequency: Rated frequency
  - Outlet pressure: During the test, the outlet pressure of the flowmeter should be higher

than atmospheric pressure.

• Inspection items

Inspection items	Quality standards	Test Methods
Dimension inspection	Within the tolerance range of standard drawings Small diameter: around -1 mm in total length Large diameter: around -3 mm in total length	After manufacturing the measuring tube, the overall length is within the tolerance of the standard drawing when installing, and the interval is inspected with a 3D measuring device (calibration completed) to see if it is within the tolerance range.
Visual inspection	The coating thickness should be within tolerance and there should be no peeling or scratches on the exterior.	Inspect more than 10 points mainly inside the measuring tube with a film thickness gauge, and it should be within the tolerance range. Examine the exterior and make sure it is clean.
non-destructive testing	Pressure-resistant quality assurance at the melting point 1.5 times safety guarantee of withstand pressure	In order to check the pinhole or internal pressure of the welding part, apply the internal pressure 1.5 times the allowable pressure and operate it for 15 minutes. There should be no leakage or pressure loss.

(b) Insertion Paddle wheel Flow Meter

(1) Material & Function
- Operating range : 0.3 - 8 m/sec
- Frequency : 53Hz per /sec Nominal
- Connection : 1½” NPT or BSPT, Flanged ANSI/PN/JIS optional
- Linearity : ± 2%
- Repeatability : 0.5% typical
- Max operating pressure rating : 100Bar
- Temperature range : -40 to 125°C
- Materials
  - Body: 316 stainless steel
  - Housing: Aluminum (Hard anodized) stainless steel optional
  - Rotor: Stainless steel
  - Shaft: Tungsten carbide (ceramic)
- Power supply : Self powered (Battery)
- Outputs : Flow transmitter / 8 digit LCD display (specify separately)

(2) Installation
- Fitting Position

Bubbles, turbulence, and sediments will cause improper operation. For best operation, mount 30° to 150° off vertical on horizontal runs. Allow a straight run of at least 5 pipe diameters upstream and 3 pipe diameters downstream to insure optimal flow measurement.

- LCD Display
  A broad range of displays are available for self-powered and remote applications with a range of power options.

4.2.5 Sluice Gates and Accessories

(a) Designs and Drawings to be supplied by the Contractor

(1) No Drawings other than those included in the Tender Documents will be provided by the Employer, and the Contractor shall provide the complete drawings required for the fabrications of the gates and accessories.

(2) Before commencement of manufacturing the equipment the design criteria, calculations, dimensioned drawings and diagrams showing all details of the equipment and materials to be used shall be submitted to the Engineer for approval. These drawings and calculations shall be submitted within sufficient time allowance to permit modifications to be made if such are deemed necessary and instructed by the Engineer without delaying the completion of the Contract works

The Drawings shall be modified by the Contractor as necessary if requested by the Engineer and re-submitted for final approval.

(3) Any fabrication or procurement prior to approval of the Drawings and document shall be at the Contractor's risk.

(4) After approval of the Drawings by the Engineer , the Contractor shall supply the approved drawings to the Employer and the Engineer.

(5) It is to be understood, however, that approval of the Drawings will not exonerate the Contractor from any responsibility in connection with the Works.

(6) Numbers of Drawings to be submitted to the Engineer shall be as follows:

During the Work To the Engineer

Drawing for approval 5 copies

Approval drawings 5 copies

After completion of the work Complete sets of bound prints 5 set

(7) Further copies of particular drawings are to be provided if required

(b) fabrication and processing

The manufacturing and processing of Sluice Gates are manufactured by precision processing for sliding and rotational parts using specified materials.

(1) Gate Frame

- A guide (liner) for opening and closing the gate must be installed on gate frame
- The thickness of the main part takes into account corrosion.

(2) Gate Leaf

- Gate leaf has a structure with ribs that have sufficient strength and rigidity, and corrosion must be considered for the thickness of the main part.

- In the calculation of the strength of Gate leaf, it is assumed that water pressure of the indicated water level is applied to the pressure side and there is no water in the opposite side.

(3) Seat (Gate frame seat, Gate leaf seat)

- The seat is installed on the gate frame and gate leaf. Shaft diameter is designed and manufactured with at least 150% of the torsional load received by the gate leaf
- The material of the seat is stainless steel (EN 1.4301) or Bronze (ASTM B62 C83600).
- The seats must be precisely finished after installation on the gate frame and gate leaf, so that there is no problem in watertightness.

(4) Wedge

The wedge plate is firmly installed on the gate leaf and gate frame made of stainless steel and brass.

(5) stopper

The stopper is installed on the gate frame.

(6) Stem

- The stem is made of stainless steel or higher, allowing the body to move up and down smoothly and safely.
- Make sure the screw is fused with the screw block (Screw Black) of the head stock.
- When using pins for the part connecting the main body and the stem, use Stainless steel (AISI 410) steel bar or higher.

(7) Manual actuator

- Manual actuator is a gear type, and a handwheel or cap is attached to the end.
- Manual operation force must be 392N (40kg) or less, and in the case of a cap, the torque of the cap shaft must be 196N (20kg.m) or less.
- The opening of the gate must be indicated in degrees or percentages.

(8) Electric actuator

- The electric drive system can obtain strong operating force with a simple structure, has a fast response speed to operation signals, has no trouble even after long-term use, and can be operated remotely. The handle, manual/electric switching device, mechanical opening indicator, terminal box, etc. must be completely integrated.
- There should be no difficulty in opening and closing the sluice gate at the maximum differential pressure, and the operating time from opening to closing the sluice gate follows the manufacturer's standard specifications.
- Ambient temperature

  It must be possible to operate at an ambient temperature of -30°C to 70°C.

- Electric motor

  - The motor for gate driving is 3-phase, 400V, 50Hz, and the starting torque is large, and there should be no abnormality in frequent starting and stopping.

- Insulation grade is class F, connected to the side of the casing with a flange, and the rotating part is not exposed.

- In case of overheating of the motor coil, the motor must be protected by the temperature sensor.

- It must operate even with a voltage drop of 10% of the rated voltage.

• Reducer

Power transmission is assured by decelerating with spur gears and worm gears, and use oil bath or grease lubrication sealed types. Worm gears are made of phosphor bronze, gear shafts are made of steel gear, teeth are machine-cut with high precision, and tooth surfaces are heat-treated to ensure wear resistance.

The electric circuit must be cut off so that it has electric/manual switching function or that electric operation does not occur during manual operation. Manual operation is done with a hand wheel, and opening and closing must be possible with less than 15 kg of force. The manual handle should not rotate during power transmission. Unless otherwise noted, ensure that the sluice gate closes when the handwheel is turned clockwise.

• Torque and limit switch

- Install auxiliary limit switch that can be used in connection with torque switch (Torque S/W), limit switch (Limits S/W) and remote indicator lamp in each direction of opening and closing of the sluice gate.

- Each switch should have a dial-type scale that can be easily adjusted with a screwdriver, etc., fine adjustments are possible, and there should be no over-travel and jamming phenomenon, and it should not fluctuate due to any vibration or shock after being fixed.

- Excessive torque is required when the valve is opened from the fully closed state. At this time, the torque switch must not be opened due to excessive torque.

• Opening degree indicator

An open indicator indicating fully open, fully closed, or halfway and a continuous indicator in percentage must be attached.

• Body

The body of the sluice gate drive device is a waterproof type sealed with an O-ring.

(c) Shop Assembly

All items of the equipment shall be assembled in the shop prior to shipment, and tests shall be performed by the Contractor as may be required to demonstrate to the satisfaction of the Engineer the adequacy of the equipment and its component parts. All dismantled parts shall be properly match marked and doweled to ensure correct assembly in the field.

(1) Machine Work

- General : All tolerances, allowances and gauges for metal fits between plain cylindrical parts shall conform to the requirements of the Specification or the other approved equivalent standard for the class of fit as shown or otherwise required. Sufficient machining stock shall be allowed on locating pas to ensure true and exact to secure full contact. Journal sliding surfaces shall be polished, and all surfaces shall be finished with sufficient smoothness and accuracy to ensure proper operation when assembled. Parts entering any machine shall be carefully and accurately located and drilled from templates.

- Finished Surface : Finished surface shall be indicated on the Contractor's drawings and shall be compliance with specified inspection of the work compared to standard roughness specimen.

- Unfinished Surface : So far as is practicable, all works shall be arranged to obtain proper matching of adjoining unfinished surface, when there is a large discrepancy between adjoining unfinished surface, they shall be chipped and ground smooth, or machined, to secure proper alignment. Unfinished surface shall be true to lines and dimension shown on the Drawings and shall be chipped or ground free of all projections and rough spots. Depressions or holes not affecting the strength or usefulness of the parts may be filled in an approved manner.

- Pin and Pin Hole : Pin hole shall be bored to gauge, smooth and straight, land at right angle to the axis of member. The boring shall be done after the member is securely fastened in position. Pin shall be of hardened and ground steel positively held in position. Wheel or roller for use in gate shall be made mounted on removable pin and have self-lubricating bushing and brass washer.

- Lubrication : Before assembly, all bearing surface, journals, and grease and oil g rooves shall be carefully cleaned and lubricant. Self-lubricating bearings shall be cleaned with clean rags and greased with an approved lubricant before assembly. Solvent shall not be used on self-lubricating bearings. The specification of all approved lubricants shall be mentioned in operating and maintenance instructions.

- Balancing : All revolving parts shall be truly balanced both statistically and dynamically so that when running at normal speeds and at any load up to the maximum, there shall be no vibration due to lack of such balance, and the equipment shall be operated with the least possible amount of noise.

(2) Miscellaneous Materials

- Rubber gate seals shall be molded from a high grade, tread type compound. The basic polymer shall be natural rubber, a copolymer of butadiene and stems, or a blend or both. The compound shall contain not less than 70 percent by volume of basic polymer, and the remainder shall consist of reinforcing carbon black, zinc-oxide accelerators, antioxidant, vulcanizing agent and/or plasticizers. The compound shall have the following physical properties: -

  - Tensile strength: 210kg-f/cm2 minimum
  - Ultimate Elongation: 450 % minimum
  - Durometer Hardness (shore type A): 50 to 70
  - Specific Gravity: 1.1 to 1.4

- Compression Set (as a percent of total original deflection): 30 % at max.

(d) Protection, Cleaning and Painting

(1) General

- Except otherwise specified in the specification, all painting of the gates and accessories, and the equipment under the Contract shall be performed in accordance with this Clause.
- All parts, which will ultimately be buried in concrete, shall be cleaned and protected, before leaving the manufacture's plant, by a cement wash or other approved method. Before being installed they shall be thoroughly descaled and cleaned of all rust and adherent matter. Such cleaning shall not detrimentally affect the strength or final operation and function
- All machined parts or bearing surfaces shall be cleaned and protected from corrosion, before leaving the manufacturer's plant, by the application of an approved rust preventive lacquer, or a peelable plastic film.
- Primer shall be applied to surfaces prepared in accordance with the paint manufacturer's instructions. The surface shall be wiped clean immediately prior to applying the paint. The primer and finishing coats of paint shall be applied using the methods and equipment recommended by the manufacturer. The system selected shall have a proven life expectancy of not less than one (1) year in the atmosphere prevailing at the project site.
- Paint shall be product of reputable manufactures and its selection shall be approved by

(2) Surface Preparation

All oil, paraffin, grease and dirt shall be removed from the surface to be painted, using solvents. Following solvent cleaning, all weld spatter, slag, burrs, loose rust and mill scale and other foreign substances shall be removed by sandblasting or shot-blasting to near white metal. Surfaces not to be painted shall be protected by appropriate and adequate masking during the cleaning and painting of adjacent metal work.

All surface preparations shall be subject to approval by the Engineer before any paint is applied.

(3) Application Procedure

All paint, when applied, shall provide a satisfactory film and smooth, even surface. Paint shall be thoroughly stirred, strained, and kept at a uniform consistency during application. Paint shall not be applied when the temperature of the metal or of surrounding air is below ten (10) degrees Celsius. Surfaces shall be free from moisture at the time of painting. Painting shall be performed by brushing and/or airless spray. The first coat shall be applied immediately after surface preparation. Each coat shall be allowed to dry or harden thoroughly before the succeeding coat is applied.

(4) Surfaces not to be Painted

- Bronze, brass, surfaces of gear teeth, finished ferrous surfaces and surfaces in rolling or sliding contact after field assembly shall not be painted.
- All corrosion-resisting steel surfaces for bearings and machinery parts shall not be painted.

- On completion of cleaning, the surfaces shall be coated with an adhesive plastic film to protect the surfaces from minor mechanical damage and corrosion during transportation and storage at the Site. The film shall be stripped off immediately prior to field erection of the equipment.

(5) Paint Schedule

- Tar epoxy and/or epoxy resin paint shall be applied to the exposed surfaces of guide frames except for upper side more than ground line and all gate leaves. Each thickness of painting film shall be approved by Engineer.

- All unfinished surfaces of ferrous metal except those specified above shall be given one (1) premier and four (4) coats of chlorinated rubber paint or equivalent. Total thickness of these coats including primer coat shall be 0.2 to 0.15 millimeter.

  Commercial equipment shall be painted in accordance with the manufacturer standard practice.

- All finished surfaces of ferrous metal including screw threads that will be exposed during transportation or while awaiting installation shall be cleaned and given a heavy uniform coating of gasoline soluble, rust-preventive compound.

(e) Tests

(1) The Contractor shall submit to the Engineer for approval, during or immediately following the submission of the Drawing, and instruction procedure describing shop and site tests to be performed for commission and performance testing. The procedures shall define the sequence of the test, the equipment preparation and operation procedures to be followed and the detailed procedure for conducting the tests. These instructions shall be submitted for approval and distributed in the same manner as the Drawings.

(1) During the construction and after the installation of each item of the equipment, the Contractor shall perform the tests as described in the test procedure instruction to establish the accuracy of the assembly and to prove the adequacy of the materials and workmanship.

(2) The tests shall be approved by the Engineer. No part of the work shall be considered acceptable until it has successfully complied with these tests to the satisfaction of the Engineer.

(3) The records, data, calculation sheets and photographs shall be submitted to the Engineer in five(5) copies within four (4) weeks after the test has been conducted.

(4) Records, data, calculation sheets and photos must be submitted to the engineer in 5 copies within 4 weeks after the test is performed

(5) Test method

- Factory inspection

  - Material inspection

    Whether the specified material is used for major parts (manufacturer's Mill-Sheet, certificate from an accredited institution)

  - Dimension inspection

- Leakage inspection

  The gap in the seat part should not pass when inserting the gap gauge 0.1 mm, and check the leak by filling the seat with water while laying the seat surface horizontally.

  At this time, the permissible leakage should not exceed 1.24 liter/min (AWWA C-501 standard) for a 1m diameter.

- Visual inspection

• On-site installation inspection

- Leakage inspection

  It must not exceed 1.24 liter/min (AWWA C-501 standard) for 1 m in diameter at the designated head.

- Operational inspection

(f) Spare Parts and Tools

(1) The Contractor shall furnish the following spare parts. Any parts supplied shall be packed or treated in such a manner as to be suitable to be stored under the climate at the Site for a period of not less than two (2) years, and each part shall be clearly marked with its description and purpose on the outside of the package.

• One (1) set of manual actuator, stem, rod for each size Sluice gate

• Other necessary spare parts recommended by the manufacturer

(2) The Contractor shall furnish the tools with box necessary for maintenance purposes. The tools shall be able to disassemble, assemble and adjust equipment and include measuring equipment

(g) Operating and Maintenance Instruction

(1) The contractor shall submit to the Engineer for approval, general instructions concerning the correct manner of assembling and maintain the equipment with special reference to any recently developed features.

(2) The manual shall be submitted for approval in the same manner as the Drawings and when finally approved, twelve (10) copies shall be prepared and forwarded to the Engineer.

(3) The instruction manual shall describe in detail the erection procedure and the use of all erection equipment and measurement devices. The procedure for assembling, adjusting, operating and dismantling of each component, system and machine shall be described and illustrated. The maintenance of each component shall also be described, including the recommended frequency of inspections and lubrications.

(4) The instruction manual shall include a separate and complete section describing the normal and emergency operating procedures for the control of the equipment, and shall include easily read diagrammatic drawings of the equipment to facilitate understanding the descriptive information.

(5) The Contractor shall, in preparing the instruction manual, take into account the lack of experience and familiarity of the operating personnel with this type of equipment.

(6) The manual shall include a complete list of all drawings prepared for this Contract, the spare parts list, and a parts list shall include manufacturers code and serial number and ordering instructions. The parts list shall be detailed for only the equipment supplied and shall not include general reference or description of similar equipment which is of same model but different only in detail.

4.2.6 Screens (Trash Racks)

(a) General

screens shall be installed at the head of the inlet Main canal, Secondary canal(pipe) and Pumping Station.

Each screen shall have bar spacing of 20 mm. Each bar shall be individually supported at the bottom and at a point above top water level in the channel.

(b) Detailed Specification

Item	MC3	SC2	SC,PS1	PS2	Remarks
Type	Bar Screen	Bar Screen	Bar Screen	Bar Screen	
Material	STS304	STS304	STS304	STS304	
Screen size W x H(m)	2.4 x 4.0	2.2 x 3.0	1.8 x 3.0	1.8 x 2.5	
Bar size W x t(mm)	65 x 8	65 x 8	65 x 8	65 x 8	
Bar spacing (mm)	20	20	20	20	
Installation angle(°)	65	90	90	90	

(c) Material and Structure

(1) The screen must be made of a stainless steel(EN 1.4301) bar, and the cross section of the screen bar must be square.

(2) The support frame and plate must consider the reaction force due to its own weight and the water pressure of the screen bar.

(3) The strength calculation is based on the case where the full load is applied to one side at once.

(4) The screen must have a structure that does not have any strength problems by examining the difference in water level, the inflow of floating substances, and the inflow.

5. ELECTRICAL WORKS

5.1 GENERAL

5.1.1 Scope Of Application

The work to be performed consists of power supply to electrical equipment, furnishing main electrical panels, local control panels, lighting panel boards, auxiliary equipment and materials and their installation in all sites. Services to be provided shall include all technical engineering, the supply, testing before shipment, transportation, insurance, storage, installation, testing at each site, documentation, and commissioning of equipment, the provision of tools and spare parts and the training of operations staff for Shire Valley Transformation Program 1.

The Contractor shall design, supply, install and test all items of equipment provided for the Works. All equipment and materials including tools, accessories and spare parts shall be new and unused of first class quality, free of manufacturing defects and imperfections and shall meet the requirements of the specifications.

The Contractor shall provide complete and functioning electrical equipment that meet current applicable standards and best practice including all engineering and accessories, necessary for reliable performance under the site conditions.

5.1.2 Order Of Application

(a) On-site manual and Q&A.

(b) Construction specification.

(c) Design drawing.

(d) Statement of calculation.

5.1.3 Standards and Regulations

The requirements of this specification are the minimum requirements for all supply and performance. Specifications, designs, all materials, equipment, performance, and their manufacturing and testing shall comply with relevant ISO standard standards in the following standards and regulations approved by engineers.

1) International Electro technical Commission (IEC)

2) Institute of Electrical and Electronics Engineers (IEEE)

3) American National Standards Institute (ANSI)

4) National Electrical Manufacturers Association (NEMA)

5) American Society for Testing and Materials (ASTM)

6) European Standards (EN)

7) International Organization for Standardization / Open System Interconnection (ISO/OSI)

8) International Telecommunication Union (ITU)

9) International Society of Automation (ISA)

10) Other standards or regulations approved by the Engineer

All materials and technologies not fully specified herein or covered by approved standards must be of the same kind as those used for first-class work and must be suitable for the climate of the project area.

In addition, details not described in this specification must conform to specifications prepared by government agencies or related agencies, such as rules and regulations of local enforcement agencies and requirements of local power companies.

5.1.4 Bid Drawings

The contractor shall carefully review all specifications, quantities, and details specified in the bidding drawings and manuals presented by the client, and shall inquire before bidding if there is any objection.

5.1.5 Construction Plan

After the contract, the contractor must submit a construction plan for the electricity and SCADA SYSTEM construction to the supervisor for approval.

5.1.6 Manufacturing Drawings

(a) Composition Of The Manufacturing Drawings

The contractor shall prepare a production drawing including the following matters in accordance with the bidding drawing and manual presented by the client.

(1) Overall assembly.

(2) Partial details.

(3) Installation basic map.

(4) Manufacturing, equipment, and painting methods.

(5) Inspection matters and methods.

(6) Major partial structure statement (wireless bridge antenna pole)

(b) Submitted Device Items

(1) POWER DISTRIBUTION PANEL

(2) SOLAR POWER

(3) WIRELESS BRIDGE ANTENA POLE

(c) Submission Time

Within two months from the date of the contract, the contractor shall submit four copies of all drawings and related data mentioned in the front and rear paragraphs to obtain approval from the supervisor.

(d) Review Of Production Drawings

The contractor shall review the contract drawing in detail before submitting it to the supervisor and mark the "Review Fill", and the drawing shall not be received unless this "Review Fill" is indicated.

5.1.7 Construction Related To The Construction

The contractor shall always be present during the construction of the concrete structure with respect to the location where the facility is to be installed so as not to interfere with the construction. Since such matters cannot be implemented quickly, additional construction costs incurred are the responsibility of the contractor.

5.1.8 Electrical Power Supply System

(a) Pump Station Power Supply

As an ESCOM electric company, the pump station electricity supply must be secured from the distribution line of a local utility company. Power should be 400V, 50Hz 3-phase 4-wire power.

Low voltage power, such as lighting, water level meter, flow meter, etc., shall be supplied with 230V 50Hz single-acid two-line power.

(b) Valve Facillity Power Supply

The power supply of the valve chamber is performed by constructing and supplying solar power generation facilities. The valve operation power shall be 400V 50Hz 3-phase 4-wire.

Power, such as a water level meter and a flow meter, should be supplied by a single-phase two-line power supply of 230V 50Hz.

All individual equipment should be protected so that one failure does not cause another.

SCADA SYSYTEM equipment shall be suitable for permanent operation under the following conditions during full operational use without compromising performance, unless otherwise specified.

- AMBIENT TEMPERATURE : -10℃~ 70℃

- OPERATING HUMIDITY : 0~100%

5.1.9 Test And Inspection

(a) GENERAL

After the manufacturing, construction, and installation of each facility item in this section, the contractor shall perform the tests described in the test procedure to establish the accuracy of assembly and demonstrate the adequacy of materials and manufacturing.

The contractor must notify the supervisor of the test data in writing at least 14 days in advance.

The Contractor shall provide the professional personnel, tools, meters, materials, and other information necessary to perform the test and shall be fully responsible for the test.

All defects observed during the test must be repaired and improved by the contractor and tested until specifications are met. It should be considered acceptable until the specifications are successfully observed.

All costs required for testing and testing required in this section are considered to be included in the appropriate price of the quantity specification.

All parts that do not match the specifications and drawings must be changed without delay at no additional cost to the client.

(b) Workshop Tests

All materials, parts and assemblies thereof, entering into the plant shall be tested, unless otherwise indicated, according to the best commercial method for the particular type and class of work.

Witness tests and inspection of material may be made at the place of manufacture by the engineer unless otherwise specified. Such witnessing and inspection will be conducted so as to interfere as little as possible with manufacturing operation. The Contractor shall however comply with any reasonable request made by the Engineer concerning the method of test or correction of defective workmanship.

The testing of the specimens shall be carried out by the Contractor at his own cost and expense and shall be performed in accordance with the approved test procedure instructions.

(c) Site or Routine Tests

The Contractor shall take out the equipment from their packing and shall inspect the equipment for damage due to delivery. The Contractor shall repair or replace any damaged portion of the equipment subject to approval of the Engineer.

During the construction and after the installation of each item of equipment, control device, piping system etc., tests shall be performed as specified in this section, to establish the accuracy of the assembly and to prove the adequacy of the equipment and the workmanship. All tests shall be made upon approval of the engineer.

(d) Test on Completion

After any section or the whole of facilities under this specification has been fully installed, adjusted, tested and approved and parts under other sections for operating the plant are fully installed, the Contractor shall conduct the tests on completion in the presence of the engineer to demonstrate that the facilities has been correctly installed, all necessary adjustment and setting made, and is free from vibration and leakage under load, and meets the specification in all respects.

Insulation resistance test and continuity test shall be done during / after installation cables which are witnessed by the Engineer. The results should be recorded and submitted to the Engineer.

5.1.10 Name Plates

All major items of equipment shall be provided with a securely fastened nameplate showing the maker's name, model, serial number, year of manufacture, main characteristic data of the respective equipment and further relevant information specified in the applicable standards or necessary for the proper identification of the equipment involved.

The Contractor shall also supply and install label plates and other labeling (of the screw-on type) for control panels and other places where required for operational, functional and safety reasons.

The labeling, size of the plates, available language and their location shall be subject to approval of the engineer.

A sample label-plate (with indication of the material used) with lettering shall be submitted for this purpose. The sizes of the plates shall be standardized wherever possible.

5.1.11 Packing

All equipment shall be carefully packed so as to withstand the duration of transport whether by sea or land including packing list in a waterproof envelop. Electrical equipment shall be fully protected against moisture during transit and storage. All items of material shall be clearly marked for easy identification against the packing list

All cases, packages etc., shall be clearly marked on the outside to indicate the total weight, to show where the weight is bearing and the correct position of the slings and shall bear an identification mark relating them to the appropriate shipping documents.

Cases which cannot be marked as above shall have metal tags with the necessary marking on them. The metal tags shall be securely attached to the package with strong steel wire or equivalent.

The shipping mark shall consist of information such as consignee, contract number, port of destination, item number, if applicable, package number in sequence and quantity per package, description of contents, gross weight, cubic measurement.

The finished surface of the equipment and the portion embedded in concrete shall be protected by rust preventive means.

The Contractor shall be entirely responsible for ensuring that the packing is suitable for transport of electrical equipment.

5.1.12 Delivery

The Contractor shall deliver all facilities including contractor's equipment provided under this section to the site in adequate time for its preparation and erection according to the construction time schedule.

The Contractor shall have responsibility of inspect the cargoes at the site upon arrival of the cargoes and shall report in writing the particulars, quantities, conditions, and damages of equipment to the engineer.

5.1.13 Storage at Site

The Contractor shall be responsible for the adequacy of all protection. The Contractor shall arrange at his own expense for covered storage or other protection of all materials and equipment against corrosion and mechanical damage. Any corrosion or damage that may occur to any item of the facilities shall be made good before that item is to be installed at the site.

All cases containing important machinery and electrical equipment shall be stored in the warehouse which shall be provided by the Contractor.

5.1.14 Spare Parts

The Contractor shall supply spare parts for maintenance and repairs which are goods for a period of not less than three years operation. The items of spare equipment and parts to be supplied shall be equal or better than those recommended below but not be limited to.

All the spare parts and equipment shall be supplied with respective service manuals by contractor, and shall be clearly marked with its description and purpose on the outside of the packing, ready for long-term storage indoors.

Common parts and spare parts shall be interchangeable

(a) Electrical materials

(1) MCCB and ELCB : 3 pieces per each type used in panel

MCCB (4P 100AF, 4P 50AF, 2P 30AF), ELCB (3P 30AF,2P 50AF, 2P 30AF)

(2) MC : 3 pieces per each type used in panel

(3P 11KW, 3P 5.5KW, 3P 3.75KW, 3P 2.2KW, 3P 1.5KW)

(3) General fuse & VT primary fuse : 20 pieces (each)

(4) SPD (Power, Signal, CCTV) : 3 pieces (each)

(5) Transducer (V, A,) : 3 pieces (each)

(6) EOCR(Digital Display) : 3 pieces

(7) AS, VS and S/S : 3 pieces (each)

(8) Push Button Switch(Lamp) : 20 pieces (each)

(9) RELAY : 20 pieces (each)

(b) Remote Terminal Unit

(1) CPU and Power Supply : 5 pieces(each)

(2) D/I Module (32P,16P) : 5 pieces(each)

(3) D/O Module (32P, 16P) : 5 pieces(each)

(4) A/I Module (8P,16P) : 5 pieces(each)

(5) Distributor. : 2 pieces

(6) NOISE FILTER : 5 pieces(each)

(c) Sensors

(1) Water Level Sensor : 1 Set

(d) CCTV

(1) Camera : 1 Set

(e) Wireless

(1) Wireless Bridge : 1 Set

(2) Hub : 1 Set

(f) Solar

(1) Inverter : 2 Set

(2) MPPT(Controller) : 2 Set

(g) GENERATOR

(1) 5KW : 1 Set

(2) 10KW : 1 Set

Any other recommended spare parts and accessories by the Contractor and/or manufacturers.

5.2 ELECTRICAL SPECIFICATION

5.2.1 Electrical Panels

All electric panels, such as electric switchboards and RTU located indoors in the control room and lighting panel boards for supplying low power to the control room, shall be manufactured in stand type or wall-attached type and shall be waterproof accordingly. The contractor shall prepare a manufacturing drawing including a list of materials and parts with reference to the design book. The contractor shall prepare the production drawing and implement the production after approval by the supervisor. The part list should clearly indicate the dimensions and manufacturer.

(a) Drawings and Documents to be Submitted

The contractor must submit manufacturing drawings and documents for approval prior to manufacture. One original copy and three copies of the manufacturing drawings and documents must be submitted to the engineer for approval with the following suggestions.

(1) Manufacturing schedule charts

(2) Manufacturing drawings

- Single line diagram and three lines diagram
- Out line and arrangement drawing of each panel
- Equipment assembly drawing inside of panel
- Foundation drawing and view details of each panel side
- Sequence diagram and catalogues of equipment

(3) Manufacturing specification and data sheets

(4) The list of material to be supplied and testing guide book after manufacture

(5) Delivery documents

- The list of various materials and parts to be supplied
- The guide book for operation and maintenance
- Spare parts and tools list
- Performance test guide book after field installation
- The characteristics and handling manual of circuit breaker and protective instruments
- Final manufacturing drawings and documents including catalog of various equipment to be used.

(6) Equipment accessories and miscellaneous

(7) The list of material to be supplied and testing guide book after manufacture

(b) Structure and Equipment of Electrical Panels

(1) An electric panel.

The panel structure.

- Material and type: Self-reliant steel sheet for indoor use.
- Thickness: 3.2t (door) and 2.3t (others)

Size: Refer to the drawing.

Channel base frame: 100mm x 50mm x 5t

(2) Basic manufacturing items.

- For efficient maintenance, electrical components should be detachable from the electrical panel.

- Hooks shall be attached to the top of the panel that is not fixed for transport. Assembly bolts shall be supplied for channel base and panel installation.

- It should include a bus bar for supplying power to the branch circuit as well as a bus bar for grounding.

- Operations should be visible from the outside without opening doors or windows, and there should be an integrated lock and master key.

- The electric panel shall use an internal power socket and an LED lamp to save energy.

- A label indicating the purpose of the part should be attached to the front of the electric panel.

- All panels should be able to withstand pests. The panel cable inlet must be waterproof and sealed quickly after installing and connecting cables and obtaining approval from the supervisor.

- All panels should be provided with a natural ventilation system to prevent temperature rise of the inner panel.

(3) Electrical instruments and meters

a) AC Volt meter

- Applicable standard : industrial standard, for indoor
- Type : wide angle type
- Rated voltage : refer the detailed drawings
- Rated frequency : 50Hz
- Accuracy class : ± 1.5 %

b) AC Am meter

- Applicable standard : industrial standard, for indoor
- Type : wide angle type
- Rated frequency : 50Hz
- Accuracy class : ± 1.5 %

- Am meter on motor circuit is protected type with ample over lode scale from the impact of the starting current and ensure of long life

c) Voltage transformer

- Type : resin mold type
- Primary voltage rating : refer the detailed drawings
- Rated frequency : 50Hz
- Accuracy class : 1.0 grade

d) Current transformer

- Type : resin mold type
- Voltage rating : refer the detailed drawings
- Primary current rating : refer the detailed drawings
- Secondary current rating : 5A
- Rated frequency : 50Hz
- Accuracy class : 1.0 grade
- Current transformers shall be capable of withstanding without damage the peak and rated short-time currents of their associated equipment

e) Digital Instruction(Ammeter,Voltmeter,Power Factor Meter)

- Input : Dc 4~20ma
- Display : 4digit Led
- Output : Relay Contact Point, Ssr Operation, Dc 4~20ma

f) Mccb

- Products Suitable For The Above Criteria(5.1.3) Or Those With Equal Or Greater Performance Should Be Used
- Type : As The Standard, It'S More Than 10ka
- Rated Voltage : 600v
- Rated Current : Follow The Design Drawing
- Rated Cutoff Current : Follow The Design Drawing

g) Translator(Voltabe. Current)

- Rated Voltage : 110v

- Rated Input Current : 5a
- Rated Output Current : Dc 4~20ma Or Dc 1~5v

An ammeter used for starting an underwater motor prevents impact by using an excess scale of 300% marked in red on the rated current.

(4) Cabling and Wiring

Unless otherwise specified, electrical cables and wires in accordance with international standards should be used.

The contractor shall install with care not to damage the cladding of all cables and wires is not damaged.

All cables and wires should be clearly labeled on the insulating surface.

(5) Phase and Color of Cables

When looking at the front of the panel, the standard phase placement should be left to right for AC 3-phase and single-phase circuits, top to bottom and front, left to right for DC polarity, and P-N from top to bottom.

The displayed colors of each AC stage should be black for stage 1, red for stage 2, blue for stage 3, and white for neutral stage.

Cable construction should be provided with the following colors on cables and wires so that they can be identified by the approval of the supervisor.

Phase and Polarity Color

Description	Phase and Polarity	Color
1) AC–Three phase 4 wire	First phase Second phase Third phase Neutral	Black Red Blue White
2) DC:	Positive Negative	Red Blue
3) Grounding wire		Green

5.2.2 Generation

ITEMS	DESCRIPTION		
Capacity	6.5kw	10kw	17kw
Engine	14PS	25PS	35PS
Engine Type	AIR-COOLED,SINGLE	AIR-COOLED,V-Twin	AIR-COOLED,V-Twin

Fuel	Gasoline.		
Fuel Tank	20L	26L	26L
How To Start The Engine.	Automatic start (add remote start option)		
V, Hz	400/230V, 50Hz		
Battery voltage for all systems	24V DC		
Control panel	Mounted Type		
Voltage Control Format.	Compound. AVR TYPE		
Size	670*530*550	830*620*760	1000*800*900
Weight	90KG	130KG	200KG

Sufficient fans shall be supplied to ensure the adequate ventilation of the engine room. Also, the engine generator set shall be designed and installed on anti-vibration pads to minimize vibration and noises.

5.2.3 Solar Power System

(a) Solar Panel

ITEMS	DESCRIPTION
Nominal Power	440 - 460 Wp
Efficiency	Max 20.9%
Maximum System Voltage	1500 V
Wind/Snow Load	2400/5400 Pa
Format	2163mm × 1030mm × 35mm (Including the frame.)
Weight	25.5 kg

(b) Enclosure(Battery, Inverter)

(1) The enclosure (battery and inverter) located inside the valve control chamber should be manufactured in a stand type to supply RTU power, water level meter, and flow meter low power, and should be able to lower heat by installing ventilation facilities. A manufacturing drawing including a list of materials and parts should be prepared with reference to this specification and detailed design books. The contractor shall prepare the production drawing and start production after approval by the engineer. The parts list should clearly indicate the dimensions and manufacturer..

(2) Drawings and Documents to be Submitted

The contractor must submit manufacturing drawings and documents for approval prior to manufacture. One original copy and three copies of the manufacturing drawings and documents must be submitted to the engineer for approval with the following suggestions.

a) Manufacturing schedule charts

b) Manufacturing drawings

- Single line diagram and three lines diagram
- Out line and arrangement drawing of each panel
- Equipment assembly drawing inside of panel
- Foundation drawing and view details of each panel side
- Sequence diagram and catalogues of equipment

c) Manufacturing specification and data sheets

d) The list of material to be supplied and testing guide book after manufacture

e) Delivery documents

- The list of various materials and parts to be supplied
- The guide book for operation and maintenance
- Spare parts and tools list
- Performance test guide book after field installation
- The characteristics and handling manual of circuit breaker and protective instruments
- Final manufacturing drawings and documents including catalog of various equipment to be used.

f) Equipment accessories and miscellaneous

g) The list of material to be supplied and testing guide book after manufacture

(3) Structure and Equipment of Electrical Panels

a) Enclosure Structure

- Material and type: Self-reliant steel sheet for indoor use.
- Thickness: 3.2t (door) and 2.3t (others)
- SIZE : 1400(W) x 800(D) x 1500(H)

Size: Refer to the drawing.

Channel base frame: 100mm x 50mm x 5t

b) Basic manufacturing items.

- For efficient maintenance, electrical components should be detachable from the electrical panel.

- Hooks shall be attached to the top of the panel that is not fixed for transport. Assembly bolts shall be supplied for channel base and panel installation.

- It should include a bus bar for supplying power to the branch circuit as well as a bus bar for grounding.

- A label indicating the purpose of the part should be attached to the front of the electric panel.

- All panels should be able to withstand pests. The panel cable inlet must be waterproof and sealed quickly after installing and connecting cables and obtaining approval from the supervisor.

- All panels should be provided with a natural ventilation system to prevent temperature rise of the inner panel.

(4) Controller

ITEMS	DESCRIPTION
INPUT	
PV Voltage Range	80V ~ 150V
PV Max Current	12.5A
OUTPUT	
Voltage	DV 12V/24V/48V
Max Current	20A
Max Power	1kW(DC48V /20A)
Switchover Time	0ms (on-line Type)
Internal BAT Capacity	610Wh
Size	483(W) x 410(D) x 88(H)

(5) Standalone Inverter

ITEMS	DESCRIPTION
Rated Input	DC13.4V(11.0V~16.0V)
Rated Output	2kW/220V(±3%)
Maximum surge output.	4kW(±10%)

Efficiency.	normal 91% / max 86%(±3%)
No load, current.	1.5A(±0.3A)
Grounding	D
Input low voltage stop/re-operate.	10.0V / 11.4V(±0.5V)
Input high voltage stop/re-operate.	17.0V / 15.4V(±1.0V)
Temperature range / Re-operation	-35℃ ~ 75℃/ 58℃
The temperature of the fan operating temperature.	40℃
International standard certification.	O
Cubicle specifications.	225 x 89 x 480
Product specifications.	5.5kg

(6) Battery

ITEMS	DESCRIPTION
Voltage	12V
Capacity(AH)	200
Cubicle specifications.	509(L) x 274(W) x 218(H) x 256(TH)
Weight	55kg

5.2.4 Conduit and Accessories

Installation of all conduit and conduit accessories must comply with local regulations and IEC standards unless otherwise approved by the supervisor.

Cables and wires between electrical panels and various electrical equipment should use piping.

The cable pipes buried underground shall be installed at least 0.6m underground. However, if a high-pressure load is expected, it must enter the ground at least 1.2m.

5.3 INSTALLATION WORKS

5.3.1 Installation Of Equipment

Equipment and facilities shall be installed in accordance with the drawings and this standard. All tools and consumable materials required for installation work must be provided at the contractor's own expense.

5.3.2 Materials Furnished With Equipment And Installation

Materials and parts must not rust and must be greater than or equal to the standards approved by the supervisor.

Cable and wiring materials shall have sufficient voltage and current capacity for electrical equipment.

Outdoor cables should be waterproof. In addition, this cable should be able to withstand high temperatures caused by direct sunlight without compromising its original function.

Cables and wires must be installed embedded in the wire pipe.

The cover of the manhole should be made of cast iron and impermeable structures and should be durable enough to withstand the pressure of heavy objects such as vehicles, trucks, etc.

5.3.3 Underground Cables

Underground cable installation shall be carried out according to the following methods.

After preparing an appropriate depth and width of 50cm, fill the 10cm thick bed sand and stamp it.

The cable should be placed on the sand of the bed and no stress should be applied. Sand should be filled up to 10 cm above the cable.

All steps of excavation, sand filling, cable unloading and final filling should be inspected by an engineer.

Cover the underground line with a 300 mm wide and 0.5 mm thick PVC warning tape at a position 30 cm above the underground line to be buried and perform a backfill.

Cables across roads and crossings should be protected by steel pipes.

5.3.4 Grounding Systems

All electrical equipment must be properly grounded.

Unless otherwise specified, ground work shall comply with the requirements of ESCOM electrical regulations or internationally approved work standards in relation to the type and structure of ground.

(a) Grounding rod and wire.

(1) The material of the ground rod and the wire is in accordance with the specifications and detailed drawings.

(2) Ground rod of a complete copper rod with a diameter of 18 mm or more and a length of 1.8 m or less.

(3) The ground wire shall be a green polyvinyl insulated ground wire having flame retardancy, moisture resistance, and abrasion resistance (GV).

(4) The wire to be installed underground shall be connected to the ground rod with a spiral wire having the same or more cross-sectional area of the ground wire.

(b) Ground connector.

(1) A compressive connector can be used without cutting each conductor.

(2) All connections of conductors in the equipment shall be performed with pressure type connectors and screw bolts, screws and snap rings/washers.

(3) The conductor must be passed for the measurement test of resistance for grounding and the required measurement and material test.

(c) The ground resistance to be measured shall not exceed a resistance value of 10 ohms according to the relevant standards in any case. If this value cannot be obtained, the contractor must construct an additional ground bar.

(d) All ground work shall be installed by an engineer, and the measured ground resistance value shall be reported in writing to the engineer after completion of the work.

(e) The contractor shall supply a complete grounding device. Accurate burial locations of equipment such as conduit, cable, ground rod, and manhole shall be indicated on the completion drawing and submitted to the supervisor.

6. SCADA SYSTEM

6.1 GENERAL AND OBJECTIVES

The Supervisory Control and Data Acquisition System (SCADA) shall be installed as part of the Shire Valley Transformation Program 1 to increase capabilities of the water resource management organizations to reduce the natural hazards and to improve irrigation efficiency.

The main objectives of SCADA system for integrated monitoring and operation in the irrigation infrastructures are as followings:

1) To minimize the hazards expected from the flood and drought damage due to climate change

2) To improve irrigation efficiency and reduction of the operational costs

3) To provide, analyze and record data on rainfall, water levels, equipment, storages and discharges for supporting decisions and operation activities.

6.2 SCOPE OF WORKS

The works to be performed consists of supply, transfer, installation and testing of equipment for electrical and SCADA system in the project sites. The services to be provided shall include all technical and engineering services including design, supply, testing before shipment, transportation, insurance, storage, installation, testing at each site, documentation, commissioning of equipment, the provision of tools and spare parts, and the training of operations and maintenance staff for relevant organizations.

The Contractor shall design, supply, install and test all items of equipment provided for the works. All equipment and materials including machinery, tools, accessories and spare parts shall be new and unused of first class quality, free of manufacturing defects and imperfections. Furthermore, it shall meet the requirements of the design document as well as specifications under the contract.

Also, the Contractor shall provide complete and functioning equipment that meet current applicable standards and best practice including all engineering and accessories, necessary for reliable performance under the site conditions.

The contractor shall database the data posted on the RTU for each location and configure the HMI screen so that it can be observed on the website and mobile.

6.3 GENERAL REQUIREMENTS

The SCADA system should be designed, supplied and installed to meet the following requirements

(a) Modernity

The systems should be adaptable and upgradable to use the latest technology. The system architecture and design should conform to the worldwide SCADA development trends and allow easy expansion, correction, exchange and/or development of new applications in future, such as the addition/correction/exchange of control station, field stations, instrument or devices, and communication networks.

(b) Long system life-cycle

The systems and equipment/products to be supplied must have a long life-cycle, with availability for spare parts, alternative equipment or products to maintain system operations in a cost-effective manner.

(c) Long system life-cycle

All equipment must be certified to operate normally, at all times, under the climatic conditions of the project areas. The Contractor may refer to the records of the hydrometeorology station of the appropriate project sites for historical records, particularly of rainfall, humidity and temperature

(d) Operational equipment to be suitable for local climate

All equipment proposed must be mutually compatible, according to the current development of manufacturing technology, and they must comply with equipment technical specifications. The equipment proposed must be able to be upgraded by part. (Hardware or Software)

(e) lectrical power supply

Power supply should be stable and uninterrupted during operation and supported by UPS equipment with sufficient capacity and proven reliability.

(f) Technical support

All SCADA equipment must have a regular calibration schedule and temporary parts must be available for replacement during calibration, so that the system can operate continuously. The Contractor shall supply a regular maintenance service through maintenance contracts organized by the system and equipment suppliers.

6.4 REMOTE TERMINAL UNIT (RTU)

6.4.1 General Functions

(a) It should be designed for stable use in the local environment.

(b) The CPU of the RTU should be configured in redundancy to ensure stable system operation and communication.

(c) The RTU shall be of modular construction. Based on the application needs, the measurement and control capacities of RTU can easily be increased by adding extra modules. The modules shall have a design that makes them easy to be plugged in and pulled out in case of failures to quickly repair the failure.

(d) The RTU shall continuously perform self-testing during normal operation and detect the failures that may happen in the hardware or software and store the result in the memory;

(f) RTU shall provide hardware and software capabilities that allow communication and operation at a speed of 10/100 Mbps via a two-way wireless connection between RS-232, RJ-485, and Ethernet's multi-port and wireless Internet modem, radio, fiber optic cables, RJ45 cables, and Ethernet cables.

(g) The communication protocol to be used for the communication shall be compatible with the ISO 7-layer OSI model to allow the creation of a distributed monitoring and control system. However, communication protocols of the RTU should support international standards such as Modbus, TCP/IP and DNP 3.0 protocols for the open system.

6.4.2 Configuration of RTU

(a) The main control module, including the Central Processing Unit (CPU), must not miss all events occurring in the central administration and must be a real-time process controller that responds immediately to these events.

(1) The system software shall be upgradable by downloading remotely.

(2) The CPU shall be 32 bit/64 bit microprocessor with microprocessor clock speed, modular construction and plug-in type.

(b) The RTU software shall be based on a real-time, multi-tasking (processing multiple tasks at the same time) operating system

(c) The programming language shall be capable of providing a multi-tasking structure that shall accomplish multiple tasks to be defined which control multiple processes simultaneously

(d) Power supply unit for DC power sources of each equipment shall have protections such as thermal, over current and surge protection

(e) CPU

(1) Outline

The PLC consists of a microprocessor and memory, a central processing unit (CPU) that acts as a human brain, an input/output unit that connects signals to external devices, a power supply unit that supplies power to each unit, and a peripheral device that writes programs to memory within the PLC.

(2) Product specification

a) CPU

ITEMS	DESCRIPTION
Calculation method.	Repeated operation, periodic operation, interrupt operation, fixed period operation.
I/O control method.	Scanning synchronization batch processing method.
Program language.	LD, ST, SFC
Number of commands.	Operator: 18, basic functionality: 130 types+real operation function, basic evaluation block: 41 pieces
Computational processing speed. (LD)	0.042㎲/Step
Computational processing speed. (MOV)	0.126㎲/Step
Computational processing speed. (+,-)	0.602㎲(S), 1.079㎲(D)
Computational processing speed. (x)	1.160㎲(S), 2.394㎲(D)
Computational processing speed. (/)	1.134㎲(S), 2.66㎲(D)
Program memory capacity.	7MB
Maximum input/output point	input : 131,072point, output : 131,072point
Driving mode.	RUN, STOP, DEBUG
How to start.	Warm, Cold
Program port.	RS-232C(1CH), USB(1CH)
Current consumption.	980mA/ 1310mA
Weight.	257g/ 276g

b) Power Module

ITEMS	DESCRIPTION
Permissible voltage.	AC 85 ~ 132V, AC 170 ~ 264V
Permissible current.	5.5A
Permissible power outage time.	10mswithin
Protection circuit.	Overvoltage protection, overcurrent protection, overheating protection.
Insulation withstand voltage	2000VAC 1Min
Grounding	D-type grounding.

c) Communication module (Enet)

ITEMS	DESCRIPTION
Transmission speed. (Mbps)	10/100/1000
Transmission method.	Base band.
Maximum extended distance between nodes.	100m
Transmitted media.	ele: Category 5e STP(Shielded Twisted-pair)
Maximum protocole size.	1500Byte
Communication access method.	CSMA/CD
Frame error check method.	CRS32
External connection terminal.	RJ45, SFP:PADT Access, data communication.
Current consumption. (mA)	100Mbps: 560, 1000Mbps: 900
Weight. (g)	146

d) Communication module. (Cnet)

ITEMS	DESCRIPTION
Serial communication channel.	RS-232C : 1CH, RS-422/485 : 1CH
Operation mode.	P2P, Server
Data format.	Start bit: 1, data bit: 7&8, stop bit: 1&2, parity: Even/Odd/None
Motivation method.	Asynchronized way.
Insulated repeater function.	Support
Transmission speed.	300/600/1200/1800/2400/3600/4800/7200/9600 /19200/38400/57600/64000/76800/115200 bps choice
number setting.	Setting range.: 0-31
Diagnostic function.	You can check with LED and XG5000 diagnostic service.
Transmission distance. (m)	RS-232C: Up to 25m, RS-422/485: Up to 1200m
Current consumption. (mA)	480
Weight (g)	119

e) Basic base makeup

ITEMS	DESCRIPTION
CPU Number of slots.	2 Slot
Number of power slots.	2 Slot
I/O Number of slots.	6 chanel

size	346mm x 98 mm

f) DI Module

ITEMS	DESCRIPTION
Input point number	32point
Rated input voltage.	DC24V
Rated input current.	4mA
On voltage/current.	DC19V and above/3mA.
Off voltage/current.	DC11V or less / 1.7mA or less
Response time. (ON)	(1, 3, 5, 10, 20, 70, 100)ms I/O Choose from parameters.
Response time. (Off)	(1, 3, 5, 10, 20, 70, 100)ms I/O Choose from parameters.
Common (COM) method.	32/1COM
Insulation method.	Photo coupler.
Current consumption. (mA)	50
Weight (g)	0.1

g) DO MODULE

ITEMS	DESCRIPTION
Input point number	32point
Rated load voltage.	DC12/24V
Rated input current.(1point)	0.1A
Rated input current. (공통)	2A.
Response time. (ON)	Less than 1 ms.
Response time. (Off)	Less than 1 ms.
Common (COM) method.	32/1COM
Insulation method.	Photo coupler
Current consumption. (mA)	130
Weight (g)	0.1
Surge killer.	Zener diode.
External power supply.	DC12/24V

h) Al MODULE

ITEMS	DESCRIPTION
Number of input channels.	8channel
Analog input.	DC 4-20mA, DC 0-20mA, Input resistance. 250Ω
Digital output.	0~16,000/-8,000~+8,000
Precision.	Within ±0.2% (peripheral temperature 25°C) and within ±0.3% (operating temperature range)
Maximum insulation input.	±30mA
Maximum conversion speed.	250㎲/channel
Insulation method.	Port coupler insulation between input terminal and PLC power, non-insulation between channels.
Connection terminal.	18point
I/O occupancy point score.	Fixed: 64 points, variable: 16 points.
Current consumption	DC5V : 420mA
Weight (g)	140

i) AO MODULE

ITEMS	DESCRIPTION
Number of input channels.	8channel
Types of output	Current output.
Output range.	DC 4-20mA, DC 0-20mA, Load resistance. 550Ω
Digital output.	0~16,000/-8,000~+8,000
Precision.	Within ±0.2% (peripheral temperature 25°C) and within ±0.3% (operating temperature range)
Absolute maximum output.	±24mA
Maximum changed speed.	250㎲/채널
Insulation method.	Port coupler insulation between input terminal and PLC power, non-insulation between channels,
Connection terminal.	18point
I/O occupancy score.	Fixed: 64 points, variable: 16 points.
Current consumption	Internal (PLC power supply) DC5V : 190mA / External (Module power supply) DC5V : 300mA
Weight (g)	150

j) SMPS

ITEMS	DESCRIPTION
INPUT VOLTAGE	110VAC...3.1A / 220VAC.....1.6A(Full Load) FREE VOLTAGE

INPUT FREQUENCY	50/60Hz (47~440Hz or DC)
INPUT EFFICIENCY	85% typ
OUTPUT VOLTAGE (V)	24
OUTPUT CURRENT (A)	8.3
OVER CURRENT PROTECTION	Works at over 110% of rating and recovers automatically
OVER VOLTAGE PROTECTION	Works at 115~140% or rating
ELECTRICALLY ISOLATED(INPUT-OUTPUT)	AC 1,500V 1 minute, DC 500V 100MΩ (At room temperature & Humidity)
ELECTRICALLY ISOLATED(INPUT-CASE.FG)	AC 1,500V 1 minute, DC 500V 100MΩ (At room temperature & Humidity)
ELECTRICALLY ISOLATED(OUTPUT-CASE)	AC 500V 1 minute, DC 500V 100MΩ (At room temperature & Humidity)
COOLING	FAN COOLING
OPERATING TEMP.AND HUMID	0 ~ +40℃, 20 ~ 90% RH (Non Condensing)
STORAGE TEMP. AND HUMID	-20 ~ +75℃, 20 ~ 90% RH (Non Condensing
WEIGHT (kg)	1

k) Surge Protection Devices (power)

ITEMS	DESCRIPTION
Loads used.	AC220V
Surge capacity.	40KA
Voltage protection level.	1500V or less (LE-E)
Response speed.	25nsec. ㅇ ㅣㅎ ㅏ(Single MOV Type)
Exterior.	IP20 (DIN-Rail Plug-in Type)
Temperature used.	-40℃~60℃

l) Surge Protection Devices (Signal)

ITEMS	DESCRIPTION
Loads used.	4~20mA DC
Voltage protection level.	60V or less (L-L) and 400V or less (L-E)
Maximum continuous usage voltage.	25.2V DC
Maximum load current.	100mA
Surge capacity (8/20 Hz)	25kA

Impulse current (10/350)	5kA(LINE)
Exterior.	IP20 (DIN-Rail Plug-in Type)
Temperature used.	-40℃~60℃

m) Surge Protection Devices (Communication)

ITEMS	DESCRIPTION
Loads used.	4wire, 2wire
Maximum continuous usage voltage.	170V DC
Maximum load current.	200mA
Voltage protection level.	400V or less (L-L), 500V or less (L-E)
Surge capacity (8/20 Hz)	25kA
Impulse current (10/350))	5kA(LINE)
Exterior.	IP20 (DIN-Rail Plug-in Type)
Temperature used.	-40℃~60℃

6.5 COMMUNICATION NETWORK AND NECESSARY ACCESSORIES

6.5.1 Mobile Network and Necessary Accessories

This communication network provides transmission among the control center and field stations via communication module using mobile services of mobile network supplier. On-site RTU devices can communicate with control center through public networks for comparatively simple data. Communication module shall have the following specifications as the minimum requirements.

1) Type : industrial module
2) Housing : IP 30 protection
3) Frequency Band : compatible band with local mobile network supplier
4) Input Voltage : 5 to 35V DV
5) SIM Interface : 1.8V/3V/5V
6) Protection : 15kV Electro Static Discharge (ESD) protection

All mobile network modules shall be supplied with complete accessories such as antenna, cable and connectors.

The Contractor shall install complete communication networks through radio propagation test and survey field communication situation for adequate operation of SCADA system.

6.5.2 Mobile Network and Necessary Accessories

(a) wireless bridge

A PTP wireless bridge for long distances (up to 50 km transmission) using a 5 GHz frequency band is used. This wireless bridge has a built-in 23dBi MIMO antenna, supports two Gigabit Ethernet ports, and supports an effective speed of up to 700Mbps. This wireless bridge has a simple product installation method, six LEDs can easily check wired, wireless, and power connections, and requires a large amount of data to be transmitted over long distances.

Product Specification

ITEMS	DESCRIPTION
Wireless standard.	IEEE 802.11 an/ac, TDMA, IEEE 802.11 b/g/n/(setting only), M-Wave Protocol.
Radio mode	MIMO 2x2
Frequency band.	5.250 - 5.850 GHz, 2.4GHz(For settings only.)
The reception sensitivity	-71 and -97 dBm
Channel bandwidth.	5, 10, 20, 40, 80 MHz
Modulation schemes	802.11 ac: OFDM (256-QAM, 64-QAM, 16-QAM, QPSK, BPSK)
Data rates	802.11 n: 300, 270, 240, 180 120, 90, 60, 30 Mbps 802.11 a: 54, 48, 36,24, 18, 12, 9, 6 Mbps 802.11 ac@80MHz: 866, 780, 650, 585, 520, 390,290, 195, 130, 65 Mbps
Error correction	BCC, LDPC
Duplexing scheme	Time division duplex
Type	Integrated directional dual-pol panel anntena
Gain	23dBi
Interface	10/100/1000 Base-T, RJ45 x 2 (ETH2 PoE Out)
Wireless technology.	Smart station polling, smart auto-channel, adaptive auto modulation, Automatic transmit power control (ATPC)
Security	AES128
Wireless QoS	4 queues prioritization
Network operation mode.	Bridge

Network technology	Bridge, VLAN
WAN Protocol.	Static IP, DHCP client
Additional skills.	SNMP, NTP Client, Dual Firmware Image, HTML 5 Web setting screen.HTTP(S)
manage	GUI, Shell/SSH, SNMP read, WNMS, Telnet
Tool	Site survey, link test, antenna alignment, Spectrum analyzer
Discover Protocol	Bonjour, SSDP
Size	379 X 387 X 51 mm
Weight	3.6Kg
Waterproof level.	IP67

The radio propagation test and radio path surveys should be carried out by the Contractor as early as possible after the contract become effective

(b) Antena Pole

(1) Material: Melting and plating.

(2) Size: 508.3 / / 6M X 406.4 / / 6M X 318.5 / / 6M 9T

(3) Other: Ladder for backrest, circular workbench, lightning rod, etc.

6.6 CCTV

(a) Megapixel dome camera

ITEMS	DESCRIPTION
Camera	
Filming device.	1/2.8" CMOS (200Pixels)
Valid pixel.	1,945(H)×1,097(V)
Lens	4.3 (2.8~12mm)
The lowest light.	Color - 0.015Lux, B/W - 0Lux(IR LED On)
Automatic switch between day and	Day&Night (ICR), WDR (150dB)
Backlight correction.	Off / BLC / HLC(Masking/Dimming) / WDR
Night visibility.	30m
Compression method.	H.265/H.264(MPEG-4 Part 10/AVC) : Motion JPEG
Power supply	12VDC ± 10%, PoE (IEEE802.3af)
Operating temperature.	-10°C ~ +55°C

Size	Ø140.8 X H113.0mm
Weight	624g
PoE Injector.	
Interface.	RJ45포트 - 10/100Mbps
Performance	oE (Power over Ethernet) - Max. 19Watt
Input power	100~240VAC, 50/60Hz
Size	60mm (W) x 145mm (D) x 40mm (H)

(b) PTZ CAMERA

ITEMS	DESCRIPTION
PTZ Camera	
Filming device.	1/1.9" CMOS (242Pixels)
Compression method.	H.265/H.264(Main, Baseline/High, MJPEG)
Simultaneous transmission ability.	Multi Streams(Three profiles.)
Resolution.	1920X1080(2 million pixels.)
WDR	150dB
Network.	RJ45 10/100/1000 BastT,Ethenet
LENS	6-222mm(37x power optical zoom.)
The lowest light.	COLOR 0.1Lux , WHITE 0Lux(IR ON)
IR Range	350M
Power supply voltage.	AC24V,PoE(IEEE802.3af)
PoE Injector.	
Interface.	RJ45 PORT - 10/100Mbps
Performance	oE (Power over Ethernet) - Max. 19Watt
Input power	100~240VAC, 50/60Hz
size	60mm (W) x 145mm (D) x 40mm (H)

(c) CCTV BOX

(1) Material: STS 2.0T

(2) Size: 600*700*500

(d) POLE

(1) Material: STS

(2) Size: 5M ø 101.6mm

* Must be more than or equal to the above specification.

6.7 UNINTERRUPTIBLE POWER SUPPLY (UPS)

In order to supply emergency power 230VAC, 50Hz, sine wave to the control center and field stations, UPS systems for each individual point shall be supplied with a capacity of supplying power for more than 30 minutes

The UPS must provide indications and potential free changeover contacts for all important information.

The specifications of each UPS for control center and field stations shall be;

ITEMS	DESCRIPTION
Type	Industrial Micro Processor Based
Input voltage	230V AC ± 10%, 50Hz
Capacity	1kVA (field station), 3kVA (control center)
Duty	Continuous
Overload Protection	125% of rated load for 10 min.
Backup time	Up to 30 minutes
Noise Level	< 65 dB at 1.5 meter distance
Output Voltage	230V AC ± 1%
Output Frequency	50 Hz ± 0.1Hz
Communication	Computer connection via cable

6.8 WATER LEVEL METER

Ultrasonic level sensors for water level measurement at the head of intake gates shall be provided as follows:

1) Type : Ultrasonic type non-contact
2) Level output : 4-20mA/ 0-20mA
3) Range : Refer to drawings or design document
4) Accuracy : 0.2% of the full scale
5) Sensitivity : High

6.9 TRAINING AND TRANSFER OF KNOWLEDGE

The Contractor shall program and provide on-the-job trainings to the employer's personnel nominated by the Engineer until the personnel are able to operate and maintain (O&M) the installed SCADA system.

All the documents shall be supplied for every trainee prior to the trainings including detailed O&M manuals and as-built designs and drawings after obtaining approval on the materials and supplies from the Engineer. The O&M manuals shall also recommend options for safety protection of the equipment from theft and damages.

The training program shall be organized and approved by the Engineer prior to the trainings executed so that the system manager and the operator shall be able to operate and maintain the SCADA scheme upon the completion of all training courses. The training shall be carried out at the factory and the sites at several steps though out the preparation, factory assembly, field installation and commissioning.

This training program for SCADA system shall comprise at least the followings.

6.9.1 Theoretical Training

(a) General principles of SCADA

(b) Understanding for configuration of system H/W and S/W

(c) Understanding for configuration of system H/W and S/W

(d) Data processing in the whole system

(e) Data transmission by various networks

(f) Programming of RTU

(g) Computer training and use of SCADA software

6.9.2 Practical Training

(a) Checking of each equipment

(b) Meaning of alarms and warnings

(c) Use, calibration and replacing of measuring devices (water level sensors, gate position sensor, etc.)

(d) Control of processes

(e) Control of transmission

(f) Replacement of faulty devices

(g) Maintenance of SCADA system (power supply, equipment)