CONSEIL DE DEVELOPPEMENT
ET DE RECONSTRUCTION

Republic of Lebanon
Council for Development and Reconstruction

BRISSA DAM AND RESERVOIR
Full Lining and Additional Water Diversion
Caza of Danniyeh

Tender Documents

Technical Specifications - Volume II

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TECHNICAL SPECIFICATIONS

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Part I - General Requirements

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I-A BRIEF HISTORY

The construction of the Brisa Reservoir aimed for a better distribution of irrigation water needs with the possibility of increasing the irrigated agricultural lands. The water stored in the reservoir will allow to allocate part of the flows of Brissa and Sukkar springs to be used for potable water. The reservoir volume, which will reach about 1,750,000 m3, will be collected from the overflow quantities of Brissa spring and from the hydrological catchment of surrounding basins.

The Brissa Dam is located in a high mountainous area in Dannyeh Caza- North Lebanon. The streambed elevation at the dam site is about 1940 meters above sea level. The dam is situated on Ouadi Es Sabeq water course with a water shed area of 1.65km2. in this watershed there are many springs: Brissa, Ain El Aarous, Ain Ech Chouk which emerge on levels higher than 1,700m.

Dam construction was launched in 2003 and completed in 2009. Due to the high elevation of the site, only 5 months a year were available for carrying out the works.

Figure 1: Aerial View of the Existing Brissa Dam

During excavations in the clay core footprint, large karstic voids where uncovered. They were completely cleaned and filled with concrete. In the central part of the thalweg, where limestone was outcropping or under a thin cover, clay blanket was placed under the upstream shell and on a limited area around the upstream chamber. Its thickness was around 3m.

The first impoundment of the reservoir was carried out in 2009, but the seepage was so important that water level remains only few meters above the bottom.

In 2010, based on investigations carried out to check the position of the limestone, the geologist determined the most favorable area for water infiltration, where a PVC membrane was placed. It represents almost 20,000 m² to be compared to the total area of the reservoir estimated to around ~140,000m², including the upstream face of the dam.

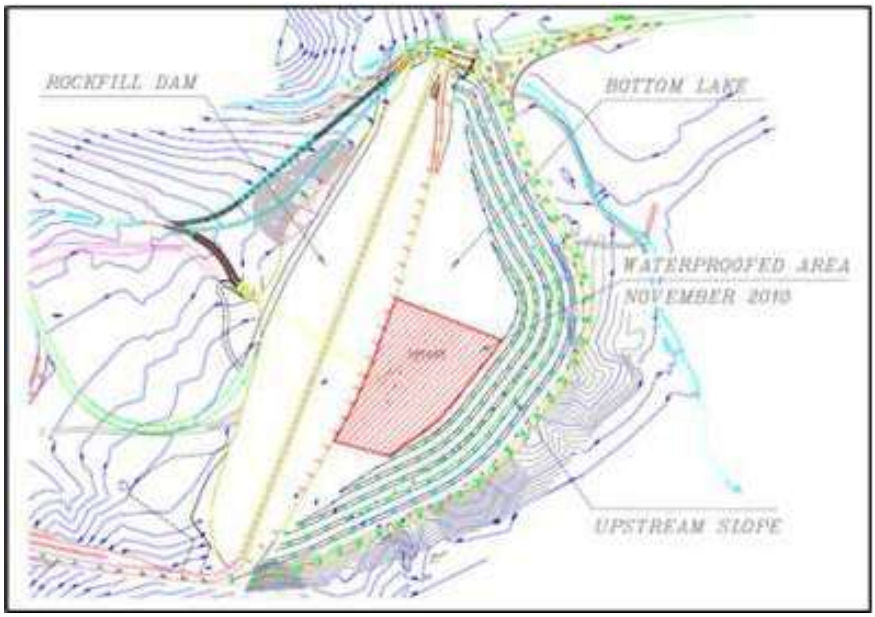

Figure 2: Location of the Installed PVC Membrane

In 2011 inflow was so small that the maximum water level reached only el. ~1954.50 ASL corresponding to a volume of almost 450 000 m3. In July 2011, after complete snow melting, reservoir level moved down continuously. Seepage rate, considering no inflow, is estimated to 30 to 40 l/s.

During the fall 2011, when the reservoir was totally empty, large bubbles where observed in the membrane covered area. This phenomena was explained by seeping water from a point higher than the reservoir maximum level.

In 2012, inflow was higher, because of the diversion into the reservoir of new springs on one hand and of the more important snowfall on the other hand. Reservoir reached el. 1962 ASL that is 7m bellow NWL. The peak was reached in the end of May and then water level was descending at the rate of 80 to 90 mm a day. Corresponding infiltration rate, considering no inflow, reaches 60 to 80l/s.

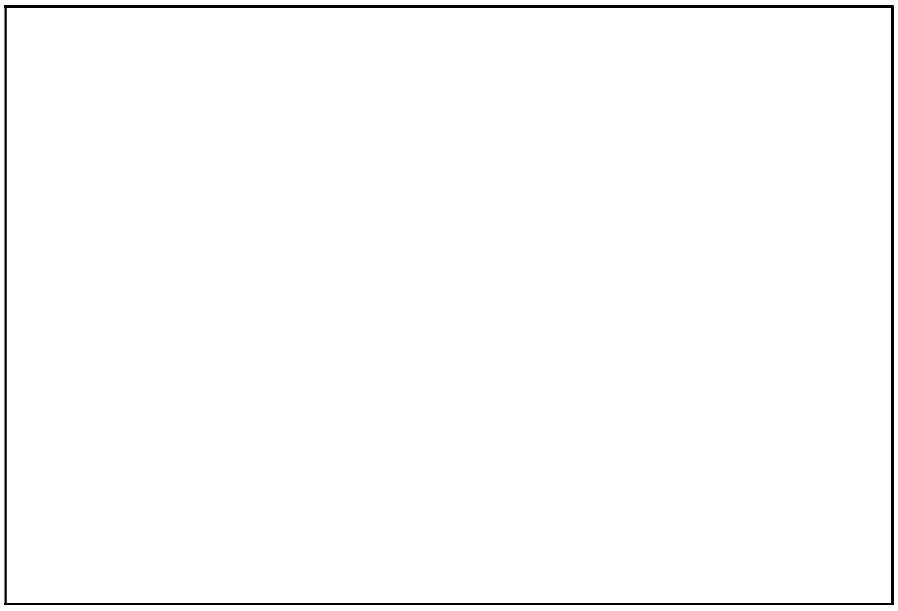

Figure 3: Reservoir Filling Curve Over the Operation Years

I-B PRESENTATION OF THE EXISTING DAM

I-B-1 Dam

The body of the dam consists of rockfill from limestone rocks compacted in successive horizontal layers 1 meter thick. The downstream and upstream faces of the Dam are protected by a selected rock paving material placed by special equipment in a sequential order thus giving the downstream face a consistent shape with a slope of 1.6 horizontal, 1 vertical.

The waterhightness of the dam is insured by a claycore protected by a draining fill and a filter material layers on the downstream side and a transition layer on the upstream side. The layers are compacted horizontally with simultaneous lifts with the dam core material in successive layers compacted to 40 cm thick.

- Type: clay core embankment dam, with external slopes of 2H/1V.
- Foundation: karstic limestone and weathered basalt
- Embankment height: 30m on the upstream toe, 45m on the downstream toe
- Crest elevation: 1 971 ASL + 0.80m parapet
- Crest length / width: ~600m / 8m
- Dam volume: ~1 250 000 m3
- Reservoir volume: 1 750 000 m3 under normal water level (NWL) at el. 1 969m ASL. It has been obtained mainly by excavating the mountain slopes.

I-B-2 Ancillary works

Overflow Structure

Overflow structure: this structure composes of a reinforced concrete lateral weir at the same level as the normal water level connected to a reinforced concrete culvert passing under the road dam and followed by a spillway parallel to the dam and drain into a natural canal to be executed and connected to the natural main water course.

- free weir of 25m length at el. 1 969.00 m ASL corresponding to NWL
- MWL under a flow of 27m3/s: el. 1 969.65 m ASL
- Minimum freeboard: 1.35m + Crest Parapet (0.80m)

Intake and washout structure

A reinforced concrete structure located at the bottom of the reservoir and composed of two rooms for the intake and washout built on top of each other. The first room is for washout control and the upper room is for intake control. This structure is constructed with concrete columns grill to prevent the entrance of any foreign objects. This structure is connected to a reinforced concrete gallery located under the dam. The tunnel uses two steel pipes: 800 mm diameter for washout, and 400 mm diameter for intake. This tunnel allows access to the intake and washout structure. This tunnel ends downstream in a control structure, which contains the valves for the intake pipes and an impact reinforced concrete stilling basin for the washout pipe followed by a riprap canal deversing in the natural watercourse. This structure will permit the access to the washout and intake pipes and to the gallery. The intake pipes are constitued from two pipes: The first is a polyethylene pipe (outside diameter 160mm) with a length of 645m. and it is used to convey water towards Brissa canal and the second is also a polyethylene pipe (outside diameter 250mm.) with a length of about 4,836m. and it is used to convey water towards El Bled canal. These pipes should be coupled with all necessary fittings, couplings accessories, pressure breakers,…

- Length : 188m from el. 1 936 US to el. 1 920 DS,

- Used for : installation of ø800mm bottom outlet and ø400 irrigation intake
- Upstream chamber : 18.4 m height, housing a butterfly guard gates of the bottom outlet and the intake
- Downstream chamber housing a hollow jet release valve for the bottom outlet. Corresponding axis is at el. 1922.25 ASL.Scope of Work

I-C WORK DESCRIPTION

The Brissa dam reservoir experienced leakage problems due to the karstification of parts of bedrock. To prevent any leakage, it has been decided to line the whole surface of the reservoir by a waterproofing membrane. An additional diversion system is also proposed in order to increase the inflow quantities to the reservoir.

The construction of the diversion and lining systems will insure additional water quantities and will decrease the infiltration inside the dam body and reservoir in order to allow better distribution of irrigation needs with the possibility of increasing the irrigation areas for more available agricultural lands. The water stored in the reservoir will then allow part of Brissa and Sukkar springs to be used as potable water for villages fed from these springs.

The retained water in the reservoir, will be collected from the overflow quantities of Brissa spring, from the hydrological catchment basin and from the new diversion system.

I-D BRIEF DESCRIPTION OF THE WORKS

The Works to be carried out under this Contract include:

- Further site investigations to facilitate final design and the release of execution drawings intended for the lining installation and related works;
- Construction design, additional studies and Analysis as necessary in light of the outcomes of the further site investigations;
- Release of the final drawings and the execution drawings;
- Site clearance;
- Access roads to the works locations;
- Surface preparation;
- Drainage system placement;
- Membrane complex installation;
- External protection installation, if required;
- Water diversion into the reservoir works.

I-E CLIMATE

The data related to climate consists of measured temperature, precipitations, humidity, wind and evaporation. This data is fairly important information to the project.

The climate of Lebanon is typically Mediterranean, with heavy rains in the winter season and dry and arid conditions in the remaining seven months of the year. The climate varies from one area to another. Three main climatic domains could be found in Lebanon at different altitudes; the littoral Mediterranean, the mountain Mediterranean and the continental Mediterranean climate. The littoral Mediterranean is a humid climate which influences the littoral zones to an altitude of 350 m above sea level. Mount Lebanon, a part of Anti-Lebanon, and the Hermon mountains are influenced by the the

continental Mediterranean climate. And finally, the Beqaa valley and the east hillside of Anti-Lebanon are influenced by the continental Mediterranean climate.

I-E-1 Rainfalls (Precipitation and Snow)

The mountain Mediterranean climate prevails on the Brissa basin. The rainfall season lasts generally from October to April and sometimes until May. 80% of the precipitations fall within the period extending from December to March with a clear peak occurring usually in January. The remaining 20% are due to fall storms and spring downpours.

The distribution of the climatic stations in and near Brissa watershed is presented below.

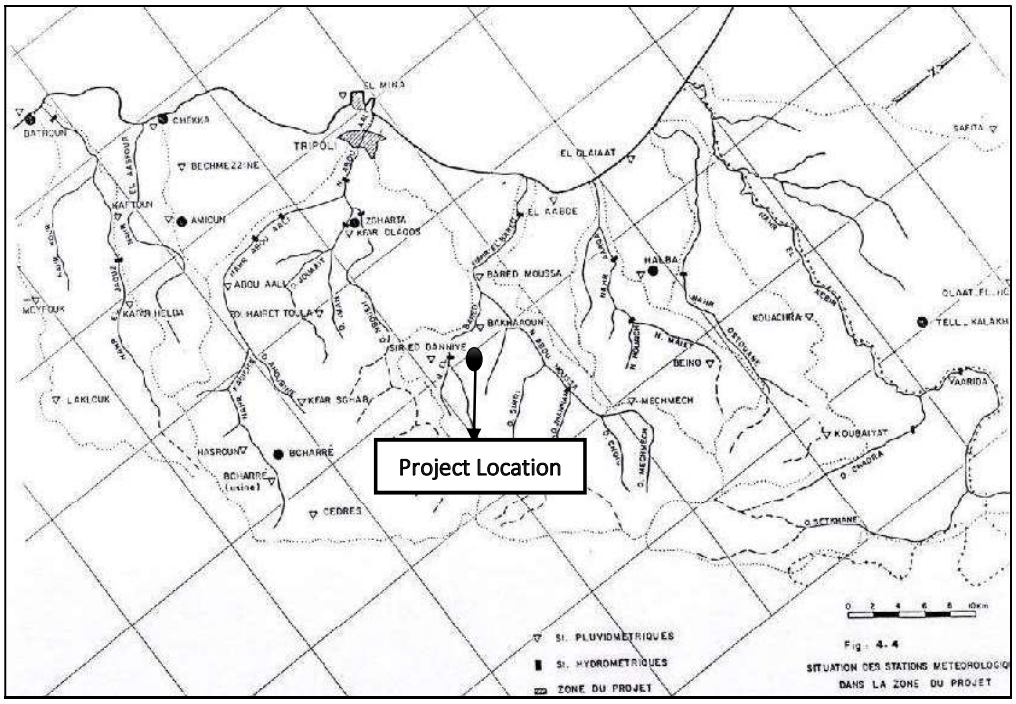

Figure 2: Climatic stations location and distribution

Furthmore, the project area is subject to heavy snow fall during winter season. The avergae annual rainfalls registered in the surrounding weather stations reached the following values:

Station	Elevation (m)	Yearly Average Rainfall (mm)
Tripoli	6	886
Halba	170	760
Abou Aali	250	914
Amioun	300	770
Sir Ed Danniye	915	1162
Becharre	1450	950

The original hydrological studies concluded the maximum daily rainfalls at the dam site, as follows:

Return Period (year)	10	20	50	100	1000
Rainfall (mm)	100	125	135	145	180

I-E-2 Temperature

The lowest monthly temperature are registerd during Jauary. Usually, August is the heatest month. The registered temperatures in the surrounding climatic stations are summerized in the fllowing table:

Monthly and Yearly Averages of Temperature (°C)

Station		S	O	N	D	J	F	M	A	M	J	J	A	Year
Tripoli	Taver.	25.7	22.8	19.0	14.6	12.8	13.3	14.9	17.5	21.3	24.0	26.2	27.1	19.9
	Tmax	29.5	27.1	23.8	18.9	16.5	16.9	18.6	21.1	24.6	27.1	29.3	30.2	23.6
	Tmin	21.5	18.8	15.4	10.9	9.5	9.8	11.1	13.7	17.1	18.8	22.1	23.0	16.0
	St	8.0	8.3	8.4	8.0	7.0	7.1	7.5	7.4	7.5	7.3	7.2	7.2	7.6
Amioun	Taver.	24.7	21.6	17.9	14.0	12.0	12.3	13.8	16.4	20.3	23.8	25.7	26.4	19.1
	Tmax	30.7	28.0	23.7	18.8	16.7	17.0	18.7	21.9	26.3	29.7	31.7	32.4	24.6
	Tmin	19.0	16.4	13.4	10.3	8.5	8.5	9.3	11.3	14.2	17.1	19.1	20.2	13.9
	St	11.70	11.6	10.3	8.5	8.2	8.5	9.4	10.6	12.1	12.6	12.6	12.2	10.7
Les Cèdres	Taver.	15.2	11.9	7.0	3.5	0.3	0.1	2.2	7.1	12.0	14.8	17.5	18.0	9.1
	Tmax	20.3	16.6	11.3	7.3	4.0	4.3	6.2	11.1	15.8	18.7	22.3	23.1	13.4
	Tmin	10.4	7.5	3.8	0.2	2.9	3.5	1.7	2.7	6.9	9.5	11.8	12.7	4.8
	St	9.9	9.1	7.5	7.1	6.9	6.8	7.9	8.4	8.9	9.2	10.5	10.4	8.6

I-E-3 Humidity

Humidity is usually high all year long. The registered humidities in the surrounding climatic stations are summerized in the fllowing table:

Station	S	O	N	D	J	F	M	A	M	J	J	A
Tripoli	66	69	67	70	71	70	67	71	72	74	73	70
Qlayat	70	67	71	74	74	74	73	74	79	78	77	73
Miniara	71	74	63	63	65	67	67	68	66	70	73	75

I-E-4 Geological Context

The previous geological surveys and the previous geotecnical investigations show that the outcropping rocks belong mainly to the Middle and Upper Jurassic. The Cretaceous is represented only by an outcrop of ferruginous sandstone 10m thick.

- The Middle Jurassic (J4) consists of limestones, dolomitic limestones and dolomites of great thickness II constitutes the solid, cracked and well karstfied base of the region. Its thickness exceeds 1000m.
- The Upper Jurassic is represented by the Oxfordian (J5), with a complete gap of the Kimmeridgian (J6) and Portlandian (J7).
- The Oxfordian is made up of three main elements:
  - The lower Oxfordian (J5a) is essentially made up of altered greenish basalts 25 meters thick.
  - The Middle Oxfordian (J5b) is formed of yellowish and whitish limestones of about twenty meters. They alternate with thin layers of basalt.
  - The Oxfordian Superior (J5c) is especially fa.it of red basalts of 30m thick
- The base of the Cretaceous is represented by the sandstones and sands of the Neocomian (C1) which flow at the corner NE of the basin and touches the water of the reservoir for about thirty meters.

From the structural point of view, the layers that flow in the southern half plunge on average 10 ° to the South, that is to say to the outside of the basin. While those that flow in the northern half plunge on average 16 ° towards the NW, that is to say towards the center of the reservoir.

I-F PROJECT CONSTRUCTION PERIOD

I-F-1 Overall Project Time Frame

The overall Execution period for the lining and diversion structures will be Two (2) years. The construction schedule will include temporary water diversion, taking advantage of the dry season at the site. The bottom outlet will be used as an important element in the diversion arrangement.

A Defects Liability Period (DLP) of Two (2) years will follow the completion of the works. This period will include the initial filling of the Dam and commissioning of the project. The contract requires the contractor to operate and maintain the facility for Two (2) years from the beginning of the DLP until final handing over to the Project Owner. Hence, the total of the Contract duration will be Four (4) years.

I-G PROJECT FLOOD AND WORKS PROTECTION

The Contractor should take all necessary meansuremtns to insure the protection of the works and structures against water floods of the watershed (50 years return period) and of the surrounding springs. Protection can consist of cofferdams and diversion canals or pipes of suitable capacities. To be mentionned that the exisiting washout and intake gallery can be used for diversion as well as the existing canals system of irrigation from Brissa and other surrounding springs.

PART II - Bidder Technical Offer

PART II– BIDDER TECHNICAL OFFER

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Note: The following requirements and clauses of the bidder technical requirements, are considered integral part of the technical specifications of the project and of the tender documents of the project.

II-A GENERAL

This section is intended to give some guidelines about the Bidders technical proposals for the lining system for the dam and the reservoir.

In principle, several lining solutions are available for waterproofing of reservoirs. The technical reliability and the feasibility of each solution are based on the service conditions that the new liner must sustain, and on site-specific constraints.

The main parameters that will affect the reliability and durability of the liner at BRISSA dam and reservoir are:

- Climatic conditions (the location of the reservoir, and the altitude > 1900m a.s.l., can result in harsh weather conditions),
- Operational characteristics (fluctuation of water level, waves, yearly total dewatering, …),
- Underground water infiltration under the membrane complex that can cause uplift of the lining system
- Settlements that could occur in the foundation soil of the lining complex
- Potential existence of voids and cavities underneath the lining complex.

The technical proposal should detail the following topics (method statement, characteristics, specifications, technical sheets, previous similar projects, certificates, calculations, drawings, …):

- Treatment of voids, cracks and cavities discovered through the geophysical investigation to be performed in the reservoir bottom and on slopes and which may cause damages to the membrane complex to be installed.
- Preparation of surfaces underneath the waterproofing and drainage systems (dam rocky face, reservoir bottom and slopes)
- Drainage system below the membrane complex and its ability to prevent uplift of the lining system
- Proposed membrane complex (lower protection layer, membrane, upper protection layer, as needed)
  - Membrane lower protection layer (e.g. anti-puncture geotextile associated during fabrication or other, if needed)
  - Type of selected waterproofing membrane (PVC or Bituminous membrane or similar)
  - Membrane upper protection layer (e.g. Geotextile and fill or geotextile and concrete slabs, or earth retaining geocomposite or other, as needed)
- Physical protection of the membrane complex on dam facing and reservoir walls (where only required by the Engineer)
- Suppliers' technical brochures, previous similar experience, similar successful applications of the selected materials, quality control standards of fabrication and quality certificates
- Speed and ease of installation of the proposed complex in light of the yearly limited period of execution (harsh winter) and the project duration
- Complex accommodation of settlements and differential movements of the subgrade and at joints, connections with rigid concrete structures, that could cause local damage of the lining systems

- Flexibility of the lining system and capacity of stretching if a discontinuity forms in the subgrade (e.g. settlements, sinkholes)
- Resistance of the lining complex to freeze/thaw and to floating debris
- Resistance of the lining system in case of seismic events
- Resistance of the lining system to puncture and risk of damage due to concentrated loads at protrusions (puncture) and tears resistance in case of cavities (burst)
- Capacity of accommodating deformations of the subgrade
- Preparation of the area which is already covered with the PVC membrane (membrane + geotextile). It should concern mainly the bubbles' zone and the boundaries in addition to the connection of the new membrane with the existing one, if feasible.
- The suitability of the proposed membrane to be connected with the existing membrane, or whether it should be removed and the method of connection between the existing PVC membrane (2mm) and the proposed new one.
- Ease of inspection and repair
- Expected life span
- Anchorage and fixation details on slopes, crests, with concrete structures and peripheries
- Deterioration under the alkali environment
- Degradation from organic and bacterial growth
- Ultraviolet resistance of different components
- Laboratory evidence of the capability of the lining system to resist puncturing, settlements, and opening of cracks and fissures
- Field evidence of the capability of the lining system to resist settlements, and opening of cracks and fissures is provided by successful precedents
- Physical and mechanical characteristics of the composite
- Modes of placement and installation (welding, anchoring, fixation, fastening,…)
- Perimeter anchorages and wherever needed
- Submersible peripheries (washout and intake on bottom of reservoir), anchoring of lining system on concrete.

II-B GEOTECHNICAL AND GEOPHYSICAL INVESTIGATION

In light of:

- The previous geological surveys, where cavities were detected under the dam foundation
- Problems of bubbles and underground water coming from upstream which causes bubbles to the installed membrane that were revealed and investigated, where important cavities were found and treated
- Some depression zones and sink holes were suspected around the dam upstream slope
- Other cavities and voids are suspected to exist in the reservoir soil and slopes

Since these voids can jeopardize the stability and may cause damages to the membrane to be installed and may form a source of incoming underground water, the Contractor is requested to perform all the necessary geotechnical and geophysical investigation to detect cavities, voids and cracks. The voids and cracks to be detected are the ones having width that can harm the membrane in case of washing of

the material filling the crack and the voids (width is related to the type of membrane), and any geological anomalies that may be the source of any future malfunction of the membrane.

The bidder should submit a method statement during bid, of the proposed geotechnical and geophysical investigation to be done to cover all these aspects. In addition, the bidder is requested to estimate the necessary quantities for these investigation during the bid phase, based on the previous geotechnical and geological investigations done in the previous phases and compare it with the quantities mentioned in the BoQ and should be included in the Bidder Technical Offer.

Contractor will be considered to be responsible about the geological, hydrogeological and geotechnical aspects concerning the foundation suitability for the membrane installation and will submit an defect insurance to the Employer for 10 years concerning the waterproofing membrane complex and annexes that should cover also all design and execution aspects.

The treatment of cavities, voids and major cracks (concrete or similar) will be paid separately to the Contractor according to the real needs and after approval of the Engineer.

II-C SURFACE PREPARATION

Based on the membrane complex type, and the supplier recommendations, the bidder technical offer should include a method statement of the surface preparation, as the roughness and the stability of the foundation is essential to the durability of the lining. The method statement, shall include at least but not limited to:

- Voids filling with necessary material specifications (plain concrete or porous concrete).
- As for the upstream face of the dam, the mode of stabilization and smoothening of the riprap face with a concrete poured on the riprap protection layer. This should penetrate the protection by almost 0.80m to block any stones movement, on one hand and on the other, to eliminate any protruding element susceptible to punch or injure the membrane.
- For the walls of the reservoir, the mode of smoothening either by removing protruding zones or by concreting or backfilling using non-plastic continuous gradation compacted material.
- For the floor of the reservoir, the mode of smoothening by motor grader work after removing all blocs setting on the surface. A systematic vibrating compaction of the surface should be carried out in order to densify the surface and locate any eventual shallow void.
- The area which is already covered with the PVC membrane complex (membrane + geotextile) should receive a preparation to be defined by the Contractor in his proposal. It should concern mainly the bubbles' zone (already treated) and the boundaries.
- In case the existing membrane can be kept, it should be dismantled, the foundation should be treated, the drainage system installed and the membrane reinstalled. Bidder should show in his technical proposal the details of the connection of the new membrane with the existing one, demonstrating a perfect continuity of the watertightness between both membranes.
- The left side abutment, where the foundation is made of slope wash, the details of treatment should be included in the technical offer. the treatment consists of a compacted embankment made of a continuous gradation, non-plastic, material watered and compacted in layers of less than 50cm thickness, in order to offer a sound foundation to the membrane.

II-D DRAINAGE SYSTEM

The main role of the drainage system under the membrane (on reservoir bottom and upstream slopes), is to intercept and convey the bypassing water (responsible of the bubbles) to the dam outlet gallery. Thus, will prevent the uplift on the membrane complex and prevent any potential damage and limit the risks of local collapse. This drainage system will allow also to limit the migration of the fine elements of the foundations soil. Whatever is the selected type of the membrane, it is mandatory to have a drainage system on reservoir bottom and on upstream slopes, which can be, as a minimum:

- For the reservoir upstream walls: A network of drainage trenches filled with granular material and surrounded by geotextile sheets and perforated pipes laid in the trenches allowing to convey bypassing water (responsible of the bubbles) to the dam culvert.
- For the dam facing, which will be stabilized and smoothed with a concrete poured on the riprap protection layer, the drainage system can be insured by selecting porous concrete for filling between rocks or simply by keeping some small voids in the concrete.
- For the dam bottom, where most of the bypassing water were noticed, a well graded drainage layer with drainage trenches and pipes are proposed. The selection of the drainage material should be done to intercept the migration of the fine elements of the foundation soil.

The bidder technical offer should include, the concept design for a complete drainage system, noting that he proposed drainages system shown on the bid drawings, is given as a minimum and as an indicative system and should be checked by the bidder and any modification or addition should be included in the technical proposal.

The bidder technical offer should also include the necessary details of the proposed drainage system beneath the membrane and should be justified technically taking into consideration that any future damage of the waterproofing system caused by underground water and uplift pressure, falls within the responsibility of the Contractor and will be included in the defect insurance of 10 years to be delivered to the Employer at the contract signature.

The drainage system will be paid per square meter for each area (reservoir bottom and reservoir slopes and berms) and based on the bidder technical offer. As for the dam facing, it shall be considered included in the price of the concrete poured on the riprap protection.

II-E MEMBRANE COMPLEX

- The membrane consists of a complex made of multiple layers providing the required watertightness and resistance to punching and other weather agents.
- Seen the complexity of the site, the bidder is invited to be in touch with specialized, internationally well reputable suppliers with sufficient experience in dams and reservoirs for this type of waterproofing projects, and this for the selection, design and later for installation of a waterproofing complex that can be suitable for this site and project and can fulfill all the requirements. However, the Contractor will remain the only responsible of the selection of the waterproofing complex and its execution.
- This complex may include, in addition to the membrane itself:
  - Membrane lower protection layer (e.g. anti-puncture geotextile associated during fabrication, geocomposite system or other), if needed
  - Membrane upper protection layer (e.g. geotextile and fill or earth retaining geocomposite or geotextile and concrete or other), if needed
- If these protection are already incorporated in the membrane itself during production or if the membrane is proven to be able to withstand alone the support hard conditions and all the external harsh weather agents (winds, UV, temperature…) and waves, the lower and upper protection

layers may be eliminated.

- The membrane itself can be a: PVC, HDPE, Bituminous or any other type of membrane that can insure the waterproofing of the reservoir and of the dam and suitable for the site conditions. The selection of the type should be done during bidding phase and included in the technical offer of the bidder. The technical note should justify the selection of the type, material, characteristics, composition, thickness, … of the selected product. In case of HDPE membrane selection, the bidder must prove, in addition to the other common requirements, the resistance of the important daily temperature variation during installation.
- The details and the characteristics of the selected complex system components, should be included in the technical offer of the bidder. The technical proposal should show that the proposed complex is:
  - Resistant to the harsh weather of the area (snow, ice, winds, significant temperature variation in the area, running surface water,…)
  - Strong to provide bridging of any local or continuous void of less than 50cm span
  - Compatible with the maximum water head (30m)
  - Having a minimum durability of 50 years
  - Resistant to UV for at least 50 years
  - Stable against winds (160km/h), waves (50cm), rapid drawdown …
  - Flexible
  - Having a low thermal expansion coefficient
  - High tensile properties (Stress at break, Elongation at break)
  - Tear resistant
  - Puncture resistant that maybe caused by the support (especially for the dam facing)
  - Stable on the slopes of the supports (dam and berms and slopes) and their geotechnical conditions with the possibility of voids formation under the complex in the future, the hydrogeological conditions and the possibility of existence of underground water pressure,…
  - High thermal dimensional stability
  - Anti-root (or provided with ani-root film) improving its durability against damage by vegetal roots
- In addition, the technical offer should also include:
  - The details, the types, the spacing and the distribution of the anchors based on the type and characteristics of the membrane, the site conditions and the stability requirements of the complex. Anchors on the peripheries are necessary.
  - Detailed mode of transportation, storage and placement, along with the staff to be mobilized and the expected daily production
  - Detailed testing to be carried out during placement to ensure a perfect future behavior
- The technical proposal of the Contractor should cover all the necessary design and details of all the above mentioned aspects and any additional aspect seems to be important for a successful installation and operation.
- The above mentioned list is not limitative and the Bidder may add any other information he considers, for the support of his product. Furthermore, the Project Owner may request any detail he considers necessary, during evaluation phase.

The membrane complex will be paid per square meter including all the components proposed by the

Contractor to satisfy all the above mentioned requirements including but not limited to the lower and upper protection (if they are necessary).

In case of a membrane complex with an upper protection, that at the same time can replace the physical protection, the bidder still have to price the item of physical protection, however this advantage will be taken into consideration during evaluation.

In case the existing membrane can be used and connected properly to the new membrane system, the bidder still has to price the whole quantities of the membrane complex, however, this saving will be taken into consideration in the evaluation of bids.

Bidder to differentiate between the upper protection, which is necessary to complement the membrane to withstand all the external weather agents and waves, and the physical protection which has the role to protect the membrane against the vandalism. The upper protection cost is considered included in the unit rate of membrane complex, while the physical protection will be paid separately (in case of necessity) and is to be installed in locations defined by the Engineer.

Furthermore, Contractor to note that in case the supporting formations slopes need to be modified for installation and stability purposes of the complex, this should be taken into consideration by the bidder and the related cost should be included in his unit rates of the waterproofing complex.

The defect insurance should cover all the above mentioned conditions.

II-F PHYSICAL PROTECTION OF THE MEMBRANE

- While the physical protection system of the membrane complex is defined in the tender documents for the reservoir bottom, it is left to the bidder to define, in his technical proposal, his proposal concerning the physical protection on the slopes (reservoir slopes and berms and dam slopes). While the main purpose of the protection system is to protect the membrane complex against vandalism, it should be able to withstand also all the external agents mentioned above and related to the membrane complex (winds (up to 160km/h), UV, waves (50cm), harsh weather of the area, slopes conditions,…). The selection of this system should take into consideration the type of the selected membrane complex as defined by the bidder himself in his technical offer.
- The selection of the physical protection system during bid phase should be justified by the bidder based on previous experience and realized similar projects with success.
- The required life span of any proposed physical protection should be at least equal to the life span of the geomembrane complex.
- Details of this system in addition to the stability details should be included in the technical offer of the bidder. Anchorage of the physical protection to the foundation (through the membrane) will be advantageous during evaluation.
- For indicative purpose, this physical protection system can be reinforced concrete slabs, earth retaining geocomposite,… however, the bidder can propose his own system based on the waterproofing complex proposed by himself and to fulfill all the requirements of the protection of the waterproofing complex.
- Stability checking of the waterproofing complex together with the physical protection system should be included in the technical offer.
- In case of a selection of a protection system consisting of earth retaining geocomposite system, attention of the bidder is drawn to the necessity to retain significant thickness of topsoil or granular materials on slopes that is also suited for erosion control. This earth retaining geocomposite should be valid to be used on slopes of the exiting upstream face of the dam as well as the reservoir slopes.

- The unit rate of the physical protection system should include all necessary works and materials for a proper system fulfilling its role and Contractor cannot claim for any additional cost (fixation, joints,…) during execution
- At the bottom of the reservoir, a 50cm thickness fill is required as a physical protection. Used material should be defined by the Contractor taking into account the circulation of trucks on the surface. The payment for this item will be based on the volume of executed fill, while the payment of the upper membrane protection (geotextile or similar) is considered included in the unit rate of the geomembrane complex item.
- The defect insurance should include also this system

II-G ATTACHMENTS

Bidder is advised, prior to submit his technical offer to consult the following attached documents (available on CD):

- Attachment 1: Geological Report March 2006
- Attachment 2: Site Visit Report on July 2012
- Attachment 3: Site Visit Report on November 2012
- Attachment 4: Site Visit report on October 2013
- Attachment 5: Geological Report on December 2009
- Attachment 6: As-Built Drawings
- Attachment 7: Geotechnical Investigation 2003-2004-2005
- Attachment 8: Original Hydrology Report
- Attachment 9: Design Report Sep. 2023

Other documents are also available in the Employer offices and can be examined by the bidder.

PART III – General Works

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III-A ABBREVIATIONS

Wherever the following abbreviations are used in the specifications or in the plans, they are to be constructed the same as the respective expressions represented :

AC	Asbestos Cement
AASHTO	American Association of State Highway and Transportation Officials
AAMA	Architectural Aluminum Manufacturer's Association
ACI	American Concrete Institute
AFNOR	Association Française de Normalisation
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AISC	American Institute of Steel Construction
AISI	American Iron and Steel Institute
AWWA	American Water Works Association
AWS	American Welding Society
BS	British Standard
CDR	Council for Development and Reconstruction
CP	Code of Practice
DIN	Deutscher Normausschuss
DTU	Documents Techniques Unifiés
EDL	Electricity of Lebanon
FSS	Federal Specifications and Standards (United States)
gpm	gallons per minute
GRP	Glass Reinforced Plastic
IEC	International Electrotechnical Commission
ISO	International Standards Organization
ITS	Institute of Technical Studies
m	meters
mm	millimeters
m^2	square meter
m^3	cubic meter
NEMA	National Electrical Manufacturers Association
NF	Normes Françaises
UTE	Union Technique de l'Electricité
VDE	Verband Deutscher Electrotechniker

III-B GENERAL

III-B-1 Standards

1. All references to codes, specifications and standards referred to in the Contract Documents shall mean, and are intended to be, the latest edition, amendment or revision of such reference standards in effect.

2. Whenever the Contract Documents require that a product complies with certain Standards or Specifications, the Contractor shall present a certificate from the manufacturer ensuring that the product complies therewith. Where requested or specified, the Contractor shall submit supporting test data to substantiate compliance.

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. The Technical Specifications could refer to one or more standards, but it is still accepted that any international recognized standard, code of practice or regulation could be applicable with the prior consent of the Engineer.

If any clarification or additional information regarding technical aspects, the Contractor must submit a request for information.

III-B-2 Equivalency Of Standards and Codes

Wherever reference is made in the Contract including the Specifications, Drawings and Bill of Quantities to specific standards and codes to be met by the goods and materials to be furnished, and work performed or tested, the provisions of the latest current edition or revision of the relevant standards and codes in effect shall apply, unless otherwise expressly stated in the Contract.

Where such standards and codes are national or relate to a particular country or region, other authoritative standards that ensure a substantially equal or higher quality than the standards and codes specified will be accepted subject to the Engineer's prior review and written consent. Differences between the standards specified and the proposed alternative standards shall be fully described in writing by the Contractor and submitted to the Engineer at least 28 days prior to the date when the Contractor desires the Engineer's consent.

In the event the Engineer determines that such proposed deviations do not ensure substantially equal or higher quality, the Contractor shall comply with the standards specified in the Contract.

III-B-3 Silence Of Specifications

The apparent silence of the specifications, plans or other Contract Documents as to any detail or the apparent omission from them of a detailed description concerning any point, shall be regarded as meaning that only the best general practice is to be used. All interpretations of the specifications will be made by the Engineer on this basis.

III-B-4 Language Of Correspondence and Records

All communications from the Contractor to the Engineer shall be in the Arabic or English language. All books, time sheets, records, notes, drawings, documents, specifications and manufacturers' literature etc. shall be in the Arabic or English language.

III-B-5 Units

The International System of (metric) Units shall be used throughout the Contract except where otherwise provided.

III-B-6 Intention Of Terms

Where "as shown", "as indicated", "as detailed" or words of similar import are used, it shall be understood that reference to the drawings accompanying the Specifications is made unless otherwise stated. Where "as approved", "as directed", "as required", "as accepted", or words of similar import are used, it shall be understood that the approval, direction, requirement,

permission, authorization, review, or acceptance of the Engineer is intended, unless otherwise stated. "Provide" shall be understood to mean "complete in place", that is, "furnish and install".

Whenever anything is, or is to be done, if, as, or, when, or where "contemplated, required, determined, directed, specified, authorized, ordered, given, designated, indicated, considered, considered necessary, deemed necessary, permitted reserved, suspended, established, approval, approved, disapproved, acceptable, unacceptable, suitable, accepted, satisfactory, unsatisfactory, sufficient, insufficient, rejected or condemned", it shall be understood as if the expression were followed by the words "by the Engineer" or "to the Engineer".

The phrases "or equal" and "or equivalent" shall be construed to mean that material or equipment will be acceptable only when composed of parts of equal quality, or equal workmanship and finish, designed and constructed to perform or accomplish the desired result as efficiently as the named brand, pattern, grade, class, make or model.

III-B-7 Intent Of Contract

The intent of the Contract is to provide for the construction and completion in every detail of the works described. The Contractor shall furnish all labor, materials, equipment, tools, transportation and supplies required to complete the work in accordance with the plans, specifications and terms of the Contract Documents.

Unless otherwise specified, the Contractor shall allow a minimum of 21 days for approval of drawings and documents by the Engineer.

III-B-8 Bills Of Quantities

Detailed Bills of Quantities shall be prepared by the Contractor in accordance with the measurement rules described in the preamble and as approved by the Engineer.

III-B-9 Operation And Maintenance Manuals

The Contractor shall submit to the Engineer for approval draft copies of the Operation and Maintenance Manuals. A separate set of instructions shall be provided for each installation. The Contractor shall incorporate any amendments or additions required by the Engineer in the production of the final Manuals.

The draft O & M Manuals shall be available on site at all times during Tests on Completion for the instructions to be verified. Any modifications found necessary shall be incorporated in the final version.

The Contractor shall supply the final version of the Operation and Maintenance Manuals prior to the issue of the Taking Over Certificate for either the whole of the works or the respective section or part of the works.

The Contractor shall, as necessary, carry out survey work, take measurements, collect details, produce drawings and undertake all other work required to enable him to prepare the manuals.

Operation and Maintenance Manuals shall be supplied written in the English and Arabic languages, and all parts and equipment listings shall be in English.

III-B-10 Work Through Private Property

In order that the necessary easements may be obtained and /or the owners of private property may be served with the requisite notices it shall be an obligation of the Contractor to supply the Engineer from time to time with full information of his program sufficiently in advance of the dates upon which the Contractor will wish to enter upon each parcel of private land.

The Contractor shall consult with Owners and Tenants (if any) and have written approval before entering on their land or cutting through any ditch, bank, hedge, wall, fence or any other form of boundary marking and he shall ascertain and carry out their reasonable requirements as approved by the Engineer in the matter of reinstatement.

III-B-11 Public Utility Mains and Services, Locating, Etc.

It shall be the responsibility of the Contractor to obtain all information available from the Public Utility Authorities regarding the position of mains and services and he shall make this information available to the Engineer as soon as he obtains it.

The absence of such information shall not relieve the Contractor of his liability for the cost of any repair work necessitated by damage caused by him to any mains or services in the course of his work and for the cost of all losses arising from the disruption.

All locating work shall be carried out in advance of further excavation work. The Contractor shall obtain all information and assistance available from the Public Utility Authorities for the locating of the mains and services and shall agree with the Engineer any trial excavation which may be necessary to confirm or establish these locations.

Any temporary or permanent diversion of mains and services will only be permitted after agreement with the appropriate Public Utility Authority.

III-B-12 Project Control

1. The Contractor shall provide within his site organization a project management section to advise and be directly responsible to the Contractor's Engineer. The duties of the section shall include the following:
   i. Planning and program preparation particularly in relation to the requirements of public authorities and the requirements to maintain water supply disposal services where careful detailed arrangements have to be made and adhered to.
   ii. Planning the execution of the works in a manner which minimizes disruption to the water supply system and will permit the efficient and effective commissioning of the water supply system and its respective components.
   iii. Ensuring adequate water supplies are maintained to all consumers.
   iv. Continuous surveillance of progress and anticipation of factors likely to affect the timely performance of the Contract.
   v. Making proposal for modification to forward planning and to the program at an early stage in the light of factors resulting from (iv).
   vi. Continuous appraisal of the Contractor's methods and routines particularly as to their effectiveness relating to speed of execution and to their effect on the community and property.
   vii. Forward planning for resource requirements taking due account of possible shortages and delays in the arrival on site of materials, plant, personnel, etc. and their mobilization for effective usage.
   viii. Acquisition and process of up-to-date information for progress meetings with the Engineer. The preparation of monthly progress reports including an update of the detailed program and cash flow forecast.
2. The project management section shall be in the charge of a professionally qualified engineer specializing in project management having had at least 10 years experience on similar projects and being versed in modern management techniques. Supporting staff this section

shall be in adequate numbers to carry out their duties and shall be of adequate ability and experience to the Engineer's approval.

3. Programs shall be based upon C.P.M. networks in precedence format and shall be prepared using a suitable P.C. - based project management software package approved by the Engineer.
4. Reporting shall be in a manner compatible with the Employer's or Engineer's requirements.

III-B-13 Quality Control

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

III-B-14 Monthly Certificates

Monthly certificates shall be submitted in an approved manner and format. The certificate shall detail the measured value of the work completed on each item of the Works. An item shall constitute a single structure or a component of a system such as a single pipeline or valve complex.

III-B-15 Progress Meetings

The Contractor shall arrange progress review meetings, to be chaired by the Engineer, at monthly intervals to coincide with submission of monthly progress submissions.

III-B-16 Proprietary Materials

Material shall be supplied in suitable containers and in appropriate batch sizes for the work to be undertaken.

The following information shall be marked:

i. Storage instructions;
ii. The manufacturer's name;
iii. Shelf life and dates of manufacture:
iv. Material identification;
v. Batch reference number;
vi. Net weight;
vii. Mixing instructions;
viii. Any warnings or precautions concerning the contents and their safe use.

The Contractor shall supply with each consignment of proprietary material delivered to the Site, certificates furnished by the manufacturer or his agent stating:

i. The manufacturer's name and address:
ii. The agent's name and address where applicable;
iii. Material identification:
iv. Batch reference numbers, size of each batch and the number of containers in the consignment;
v. Date of manufacture.

III-B-17 Rejected Materials

Should any materials or manufactured articles be in the judgment of the Engineer, unsound or of inferior quality or in any way unsuited for the purpose 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.

III-B-18 Quality

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.

III-B-19 Equipment And Services for Engineer

The Contractor shall provide the office accommodations, equipment and services described in the Contract. The Contractor shall submit to the Engineer, for approval, details of the office space to be provided before construction is commenced.

The Contractor shall supply the Engineer with mobile telephones as necessary to enable efficient communication between the contractor and the Engineer's supervision staff.

The Contractor shall also supply the Engineer, for the duration of the work, with 4x4 wheel drive vehicles (2 vehicles), brand new with minimum power of 3,500cc, to access all different site locations. These vehicles should be powerful enough to withstand all kind of driving conditions, rough roads, natural terrains and tough weathering conditions. The cost of these vehicles, in additon to the cost of maintenace and consumables, are considerd to be included in the unit rates of other items of the contract.

III-B-20 Facilities For Survey and Inspection by The Engineer

The Contractor shall make available technicians and such labor, materials and safety equipment as the Engineer may require for inspections and survey work in connection with the Works. The Contractor shall provide all necessary tackle, test equipment, access, labor, staff and any other thing the Engineer may reasonably require in order that he may safely, conveniently and quickly carry out such inspections as he deems necessary at any time during the execution of the Works including the Tests on completion.

III-B-21 Inspections By the Engineer During Defects Liability Period

The Engineer will give the Contractor due notice of his intention to carry out any inspections during the Defects Liability Period and the Contractor shall thereupon arrange for a responsible representative to be present at the times and dates named by the Engineer. This representative shall render all necessary, assistance and record all matters and things to which his attention is directed by the Engineer.

III-B-22 Approval

As soon as possible after commencement of the Contract, the Contractor shall submit to the Engineer for his approval a list of his proposed suppliers, sources of materials, construction requirements and proposed standards. No materials, plant or equipment shall be procured for the Contract without first obtaining the Engineer's approval. Samples of materials shall be submitted to the Engineer for approval as required by the Engineer. Materials subsequently supplied shall conform to the quality of the samples which have been approved by the Engineer. No standard,

method of manufacture or specification shall be changed without the approval of the Engineer. Where possible plant shall be supplied to the same standards or to compatible standards.

III-B-23 Protective Clothing

The Contractor shall provide for the Engineer, his Representative and assistants the protective clothing necessary for the proper discharge of their duties on Site.

The Contractor shall provide any necessary protective clothing and safety equipment for the use of authorized visitors to the site including the Employer and his staff and representatives and those of any relevant authority and who have reason to visit the Site.

III-B-24 Source Of Supply and Quality Requirements

All materials, manufactured articles and machinery incorporated in the permanent works shall be new, recently manufactured and shall meet the quality requirements of the Contract. They must, in all cases, be approved by the Engineer prior to their inclusion into the work.

All shipment of materials must be accompanied by a Manufacturer's Certificate of Guarantee or test certificate from an approved independent laboratory when delivered to the site. The independent laboratory shall be approved by the Engineer before any materials are submitted for tests. However, all materials delivered to the Site are subject to additional laboratory testing when requested by the Engineer even though the materials are accompanied by a certificate of guarantee or laboratory test certificate. All costs in connection with certificates of guarantee or laboratory tests and certificates shall be borne by the Contractor. Falsification of such documents shall be just cause for rejection of the materials and all cost of transportation and handling of the rejected materials shall be the sole responsibility of the Contractor.

In order to expedite the work, the Contractor shall, before placing any purchase order for materials, manufactured articles and machinery to be part of the permanent works, submit for the approval of the Engineer, a complete description of such items, the names of the firms from whom he proposes to obtain such items, together with a list of the items he proposes each firm would supply. No materials, manufactured articles or machinery shall be ordered from any firm without the written approval of the Engineer. When directed by the Engineer or otherwise specified in the Contract, the Contractor shall submit samples for approval.

If it is found after trial that sources of supply for previously approved materials, manufactured articles, or machinery do not produce specified products, the Contractor shall furnish the items from other sources approved by the Engineer.

III-B-25 Precautions Against Contamination of The Works

The Contractor shall at all times take every possible precaution against contamination of the works.

The Site and all permanent and temporary works shall be kept in a clean, tidy and sanitary condition.

The Contractor shall at all times take measures to avoid contamination of existing water courses and drains by petrol, oil or other harmful materials.

The works shall be kept clean and free from rubbish and remedial works shall be carried out as the work is progressively completed. Before requesting inspection for preliminary or final take-over of the works or any section thereof the Contractor shall inspect the works and assure himself that they are clean and in a satisfactory condition for such inspection, normal usage expected.

III-B-26 Environmental Aspects

The Contractor shall take all reasonable steps to minimize the adverse affects of both the temporary and permanent works on the environment. Before any work commences, the Contractor shall submit an environmental protection plan describing how potential adverse impacts will be mitigated. These adverse environmental impacts could be:

a. Pollution of soil and water due to improper dumping of excavated and construction material, oils used, chemicals/solvents, human wastes.

b. Erosion of soil, sedimentation and drainage due to excavation and bedding.

c. Noise and air (dust, odor) pollution due to operation of machinery and excavation.

d. Traffic increase due to trucks (sand, machinery, equipment) movement and traffic disturbance.

e. Disturbance to recreational, archaeological, touristic sites.

f. Public health and safety due to the operation of the machinery and accidents.

g. Damage to forests, agricultural land, vegetated area and its wildlife habitat.

III-B-27 Access To Properties

The Contractor shall not disrupt any private or public access way without first providing alternative arrangements.

Access to properties affected by the Works shall be maintained. Adequate road plates shall be provided for trench crossings.

III-B-28 Control Of Dust

The Contractor shall, throughout the execution and completion of the Works take all reasonable steps to avoid damage or nuisance to persons or property resulting from dust and shall carry out preventative measures, such as spraying the ground with water, and /or soil covering, as instructed by the Engineer.

III-B-29 Safety

The Contractor must cover all aspects of site safety during the Works.

III-B-30 Project Safety Plan

Before any work commences on the Site the Contractor shall submit a Project Safety Plan *(PSP)* which shall be specific to the Contract. The plan shall detail the Contractor's site safety organization, his safety rules and procedures and methods of monitoring and enforcing his procedures.

The Project Safety Plan shall cover all aspects of site safety and shall typically include the following:

a. **Health and Safety Policy and Primary Objectives**: The plan shall demonstrate that management of health and safety is an integral part of the management and co-ordination of the project.

b. **Organization and Responsibilities**: A designated competent person shall be specified as the Contractor's Safety Officer with overall responsibility for the establishment, implementation and enforcement of safety procedures and methods of working.

The Contractor's organization structure and responsibilities with respect to safety shall be detailed.

c. **Hazard Identification and Risk Assessment**: The Contractor shall assess the risks to workers and any others that require access to the site or the works or may be affected by the operations.

- A systematic general examination of each activity and assessment is to include:
- Identification of the hazards present and those hazards their operations will introduce to the site.
- Identification of the people exposed.
- The extent of the risk evaluated after considering the existing control measures.
- Further assessments to be made for new activities.
- Plant and equipment to be identified and those responsible for its provision and maintenance to be defined and designated.
- Review and revision if assessments man no longer be valid or where there has been a significant change.
- Planned review of assessments at regular intervals.
- Inform employees on the nature of the hazard and the risks identified by the assessments, the preventative and protective measures, emergency procedures and the competent personnel.
- Significant findings of assessments to be recorded.

d. **Emergency Procedures**: Effective procedures for contingency in event of serious and immediate danger. All employees shall be able to stop work and immediately proceed to a place of safety if exposed to imminent and unavoidable danger.

e. **Cooperation and Coordination**: All competent persons to liaise and assist in assessing the shared risks and coordinating any necessary measures, primarily by providing information. The Contractor to take full responsibility in coordination arrangements.

f. **Capabilities and Training**: Provision of health and safety training for all employees upon recruitment and on exposure to new or increased risks.

g. **Monitoring**: Scheduled hierarchical audit system conducted by the Contractor. Safety performance to be monitored and measured against the PSP; project procedures for safe systems of work; and specified safety performance standards.

h. **Health and Safety Performance Standards to be specified**, i.e.:

- Relevant statutory legislation
- Standard specifications (BSI/ISO)
- Approved codes of practice

i. **Specific Project Safety Plan Information**:

- Nature of the Project
  - Name of Employer
  - Location
  - Nature of construction work to be carried out
  - Time scale for completion of the construction work

- The existing environment
  - Surrounding land uses and related restrictions - e.g. premises (schools) adjacent to the proposed construction site.
  - Existing services - e.g. underground and overhead lines.
  - Existing traffic systems and restrictions.
  - Existing structures - e.g. special health problems from materials in existing structures which are being demolished or refurbished, any fragile materials which require special safety precautions, instability problems etc.
  - Ground conditions - e.g. contamination, instability, possible subsidence, underground obstructions etc.
- Existing drawings
  - Available drawings of structure(s) to be demolished or incorporated in the proposed structure(s)
- The design
  - Significant hazards of work sequences.
  - The principals of the design and any precautions that might be needed or sequences of assembly that need to be followed during construction.
  - Detailed reference to specific problems with proposals for managing these problems.
- Construction materials
  - Health hazards where either because of their nature or the manner of their use, particular precautions are required.
- Site wide elements
  - Outline emergency arrangements including access and egress.
  - Positioning of site access and egress points.
  - Location of temporary site accommodation.
  - Location of unloading, layout and storage areas
  - Traffic/pedestrian routes.
- Overlap with other undertaking
  - Consideration of the health and safety issues which arise when the project is to be located in premises occupied or partially occupied by the Employer or other authority.
- Site Rules
  - Specific sites rules which the client or the planning supervisor may wish to lay down as a result of points above or for other reasons - e.g. specific permit to work rules, emergency procedures.
- Continuing liaison
  - Procedures for considering the health and safety implications of work elements
  - Procedures for dealing with unforeseen eventualities during project execution.

III-B-31 Hazards

Potential hazards associated with the Sites may include, but will not be limited to the following:

- Any chamber, pipeline, borehole, excavation or other structure (whether above or below ground) not effectively ventilated.
- Compressed air vessels may burst explosively.
- Toxic Fumes and Gases: (generated by combustion engines, chlorine, ammonia, treatment processes).
- Asphyxiating Gases.
- Dangerous Fumes and Gases.
- Chemicals: Chemicals are stored and used in many processes. Most of them are strongly alkaline, acidic, toxic or otherwise aggressive.
- Electricity Cables: Buried and overhead cables of all voltage ratings may be encountered.

Overhead cables of all voltage ratings may be encountered. On operational sites the clearance may be lower than in highways or public areas. Hazards are as for buried cables, with the additional risk of arcing. Arcing may occur from the cables to metal objects or spray.

- Buried services: Buried water pipes may be encountered on any operational site. The water may be under very high pressure.
- Moving Machinery: Any operational plant may contain moving machinery. Much of this is automatically controlled and may start without warning.
- There is electrical plant associated with such machinery, carrying the same hazards as electricity cables.
- Noise (high frequency noise): Machinery such as engines, turbines, generators, pumps or compressors operating inside buildings may produce very loud noise. High speed machinery may produce high frequency noise. The hazards are possible short and long term hearing damage if ear defenders are not worn.
- Moving Vehicles: Any road on an operational site may carry vehicles which are relatively heavy for the class of road. Such vehicles may carry any of the chemicals or sludge's noted above.
- Tractors and other machinery may operate on unpaved areas.
- Contact Lenses: In areas where an arc flash can occur (chambers or where welding processes are carried out) wearers of contact lenses can sustain irreparable damage to their eyes. This can occur whether or not safety spectacles arc worn over the contact lenses.
  - Confined Spaces:
  - Provide, when work is in progress, radio or telephone communication, or safe visual and oral communication where this is appropriate and background noise levels permit.
  - Ensure that all electrical tools and equipment are of the appropriate type.
  - Provide appropriate protective clothing.
  - Provide hygiene facilities if appropriate.
  - Ensure that all persons entering or working in a confined space are trained and authorized to enter.

III-B-32 Water And Electricity Supply

The Contractor shall make his own arrangements for procuring water and electricity supplies, at his own expense. Public water and electricity cuts shall, in no way, justify delays in the progress of the work. He shall be solely responsible for ensuring the continuity of the water and electricity supply. For this purpose he shall install the needed number of generators and water tanks that would meet his needs.

III-B-33 Safeguards To Existing Pipes, Cables, Structures

It shall be the Contractor's responsibilities to safeguard by means of temporary or permanent supports or otherwise all existing pipes, cables, structures or other things which would be liable to suffer damage if such precautionary measures were not taken.

Temporary safeguards shall be to the approval of the Engineer and of the Undertaker or Owner concerned.

Permanent safeguards shall be to the approval of the Undertaker or Owner concerned and the Engineer.

III-B-34 Connections To Existing Pipes, Cables Etc.

The Contractor will be responsible for connections between pipes, cables etc. laid by him and existing pipes, cables etc. The Contractor shall submit to the Engineer a drawing showing the details of the connection, and shall state the date on which the particular connection could be made. The work shall not proceed until the Engineer's approval has been given.

The Contractor shall be responsible for joining up to and ensuring complete compatibility with existing pipework, cables, tubing, equipment etc.

III-B-35 Contractor’s Responsibility for Utility Properties

At points where the Contractor’s operations are adjacent to properties of telegraph, telephone and power agencies or companies, or adjacent to other property, damage to which might result in considerable expense, loss or inconvenience, the work shall not be commenced until all arrangement for the protection thereof have been made. The Contractor shall cooperate with the owners of any underground or overhead utility lines in their removal and rearrangements operations in order that these operations may progress in a reasonable manner and that duplication of rearrangement work may be reduced to a minimum and that services rendered by those parties will not be unnecessarily interrupted.

In the event of interruption to water or utility services as a result of accidental breakage, or as a result of being exposed or unsupported, the Contractor shall promptly notify the proper authority in the restoration of service. If essential public utility service is interrupted, repair work shall be continuous until the service is restored.

III-B-36 Site Access, Offices, And Transport for Engineer

The Contractor shall satisfy himself as to the suitability of the access routes he chooses for use during the Contract period. The Employer does not guarantee either the suitability or availability of any particular access route and will not entertain any claim in respect of the non-suitability or non-availability of any such route for continuous use during the Contract period. When needed for the execution of the work, the Contractor shall be responsible for building and maintaining temporary access routes at his own expense. The Contractor shall submit for the approval of the Engineer his proposal for the access routes he intends to use and build. He shall be responsible

for getting approvals from concerned authorities and/or landowners on the right-of way needed for the construction and use of these access routes.

The Contractor shall provide and properly maintain, for the duration of the Work, the offices for the use of the Engineer, his staff, the Employer and the Ministry's Representative. These facilities shall be constructed as shown on the Plans and shall be equipped and furnished as directed by the Engineer, and shall be completed and ready for occupancy within one hundred and twenty (120) days from the date of signing the Contract.

The Contractor shall, until notified by the Engineer at the completion of the Work, supply electricity, water and sanitary facilities for the Engineer's office. The Contractor shall be fully responsible for the maintenance and operation, including labor and materials, for the offices.

III-B-37 Explosives

When the use of explosives is necessary for the prosecution of the work, the Contractor shall exercise the utmost care not to endanger life or property, including new work. The Contractor shall be responsible for any or all damage resulting from the use of explosives. The Contractor shall store all explosives in a secure manner marked clearly in Arabic and English "Danger Explosives". Storage shall be in compliance with all local laws and ordinances. It is the Contractor's responsibility to contact the authorities and secure their approval of his proposed method of storage.

Where no local laws or ordinances apply, storage shall be to the satisfaction of the Engineer and, in general, not closer than three hundred (300) meters from the road or from any building or camping area. In no case shall the Contractor store explosives on the Site without prior approval of the local authorities or the Engineer.

Prior to starting any blasting operations, the Contractor shall submit a written comprehensive system of working to be approved by the Engineer. The system shall be approved by the Engineer prior to blasting. Approval of blasting plans shall not relieve the Contractor of his responsibility or liability for the safety of persons and property.

III-B-38 Setting Out of The Works

The Contractor shall prepare detailed setting out drawings and data sheets as necessary and submit them to the Engineer for approval. Any modifications to the setting out drawings or data sheets required by the Engineer shall be made by the Contractor and resubmitted for final approval. Approval by the Engineer shall be signified by the return to the Contractor of one copy duly signed by the former or an authorized member of his staff.

The Engineer will agree with the Contractor the basic information supplementary to that shown on the Contractor's Drawings such as the position of center-lines and base-lines etc. sufficient for the Contractor to locate the Works. Such supplementary information may be provided on drawings, sketches or in writing.

Should it be necessary during setting out or during construction agreed setting out details to be amended, the Contractor shall amend the drawings or data sheets or make new ones for approval as required by the Engineer.

Copies of setting out drawings and data sheets shall be preserved for use by the Contractor in preparing final records and drawings in accordance with the requirements set out elsewhere.

III-B-39 Boundaries Of Works

The Employer shall provide the Site upon which the Permanent Works included in the Contract are to be constructed. The existing boundary fences and walls shall not be disturbed without the

prior approval of the Engineer's representative and the carriage way shall be left available to traffic.

The Contractor shall not enter upon or occupy with men, tools, equipment or materials and land other than 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 the Contractor shall submit his proposals to the Engineer as to how he intends to fulfill his obligations under the Contract which shall be to the approval of the Engineer.

III-B-40 Shop Drawings / Execution Drawings

The execution drawings shall be prepared in the same manner stated thereafter in the preparation of the shop drawings.

Where the Contract Documents require the Contractor to prepare Shop Drawings, or where required by the Engineer during the course of the work, the Contractor shall submit to the Engineer Shop Drawings that shall satisfactorily establish actual details of manufactured or fabricated item and of work to be executed. They shall clearly identify materials, dimensions, thicknesses, components, attachments, relation with adjoining work and spaces, and all other pertinent information. Shop Drawings shall clarify and amplify the design drawings and other design requirements and shall, subject to the Engineer's approval, incorporate minor changes in design or construction as may be necessary to suit the requirements of the work. By submitting Shop Drawings the Contractor thereby represents that he has determined and verified all dimensions, relations to existing work, coordination with work to be installed later, coordination with information in previously submitted Shop Drawings and has verified their compliance with all the requirements of the Contract Documents.

The accuracy of all such information is the responsibility of the Contractor and in reviewing Shop Drawings the Engineer shall be entitled to rely upon the Contractor's representation that such information is correct and accurate.

The Contractor shall be responsible for and shall make any alterations in the work due to discrepancies, errors or omissions in the Shop Drawings supplied by him whether or not such Shop Drawings have been approved by the Engineer, provided that such discrepancies, errors or omissions are not due to inaccurate information or particulars furnished in writing to the Contractor by the Engineer.

III-B-41 As-Built Drawings

The Contractor shall submit final as-built record drawings to the Engineer for his review by the specified date. After review and approval by the Engineer of the final as-built drawings, the Contractor shall within 10 days thereof, produce a final set of "as-built drawings" and submit to the Engineer the following :

a. One (1) copy of each as-built drawing in transparent reproducible form.

b. One print of each as-built drawing.

III-B-42 Level Datum

Where possible, construction drawings and all levels used for construction shall be referred to the National Height Datum. The Contractor shall be responsible for obtaining the location and valves of the permanent bench marks. In cases where such bench marks do not exist, the site datum shall be agreed with the Engineer.

Levels of reservoirs, pumping stations, boreholes and the like shall be referred to the National Height datum.

Before the commencement of constructional 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 concerted in. The level of this pet 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 as agreed with the Engineer.

III-B-43 Levels And Dimensions

The levels of the ground and the levels and dimensions of existing features shown on the Drawings 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. Large scale drawings shall be taken in preference to drawings of smaller scale.

III-B-44 Benchmarks

Information giving elevations and coordinates of benchmarks in the area of the work shall be provided to the Contractor by the Engineer. The Contractor shall be responsible for preserving these benchmarks and re-establishing them in case they are destroyed.

The Contractor shall establish at his own expense temporary benchmarks he might need for the execution of the work.

III-B-45 Sign Boards and Safety Barriers

The Contractor shall provide two site sign boards in a form and to the specification specified and erect and mount on suitable temporary supports, in positions and at heights as required by the Engineer.

The Contractor shall maintain, alter, move and adapt the sign boards from time to time as instructed by the Engineer. The display of any named Subcontractors or any other information associated with the Works shall be to the approval of the Engineer.

The Contractor shall provide safety barriers to protect the public, in a form and to the specification specified. The safety barriers shall be erected each side of all open trench and other excavations and at such other locations as required by the Engineer.

Sign boards and safety barriers will not be paid for directly but shall be deemed to be included in the rates of other items of the project.

III-B-46 Flagging, Lighting, Watching and Traffic Control

Where necessary for the safety of the public or where required by the Engineer or his Representative the whole of the Works shall be properly fenced, signed and lighted from half an hour before sunset until half-an-hour after sunrise and at other times when visibility is poor. On all occasions the Works shall be properly flagged. The lamps shall be approved by the appropriate Authority and shall be kept in a clean and proper condition. The position and number of the lamps shall be such that the extent and position of the works is clearly defined and the arrangement shall comply with the requirements of the appropriate Authority. Each site of the Works shall be provided with night and week-end watchmen as may be required.

III-B-47 Temporary Works

The Contractor shall be responsible for designing and constructing any temporary works he requires to undertake the construction of the project. These works shall be to the approval of the Engineer. At Contract completion, the Contractor shall be responsible for removing all temporary works and reinstating the site unless the Employer wishes to purchase some of those works at a mutually agreed price and thereby give them the status of permanent works.

III-B-48 Cleaning The Site

During the execution of the work, the Contractor shall keep the site clean by removing and carting away to approved dumping sites all rubbish, debris, wastes, etc.

Upon completion of the work and before acceptance and final payment will be made, the Contractor shall clean the Site and property defaced or occupied by him. He shall clear in connection with the Work all rubbish, excess materials, debris, false work, temporary structure and equipment.

All parts of all types of the Work shall be left in a neat and presentable condition and as approved by the Engineer.

III-B-49 Contractor's Yards, Stores and Accommodation for Workmen

The Contractor shall make his own arrangements for all land, yards, stores, workshops, offices etc. and for all services in connection therewith.

The location of all yards, stores, workshops, offices, etc. shall be agreed beforehand with the Engineer and shall be such as to avoid obstruction and nuisance to the public.

The Contractor shall construct on the Site, or at suitable locations, secure storage compounds and storage buildings where he shall store at his own risk all equipment and plant delivered to Site and awaiting erection. The compound shall be of sufficient size to accept all such plant delivered and awaiting erection.

Storage buildings shall be weatherproof and shall be of sufficient size to accommodate all items requiring covered storage.

The storage compounds and buildings shall be completed prior to delivery of any items of plant and equipment.

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. 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 proper disposal of waste from mess rooms, closets and latrines

Materials shall be so stored as to assure the preservation of their quality and fitness for the work. Stored materials, even though approved before storage, may again be inspected prior to their use in the work. Stored materials shall be located so as to facilitate their prompt inspection. Any costs for the use of privately-owned land for storage and/or for the placing of the contractors plant and equipment shall be borne by the contractor. Private property shall not be used for storage purposes without written permission and release of the owner or lessee, and a copy of such written permission and release shall be furnished to the Engineer prior to any use of the land by the contractor.

III-B-50 Dumping Sites

The Contractor shall remove and cart away all rubbish, excess materials, debris, etc. to dumping sites approved by the Engineer. It shall be the Contractor's sole responsibility to establish the locations of these sites and get the necessary approvals from concerned authorities for using them.

Dumped material shall be spread over the whole area of the dumping site in layers not exceeding 80 cms. In case a dumping site is abandoned, the Contractor shall grade the area in an acceptable manner and to the satisfaction of the Engineer.

III-B-51 Dismantled Items

All items dismantled by the Contractor shall be considered the property of the Employer, and they shall be disposed of as instructed by the Engineer.

PART IV - Civil Works

PART IV – CIVIL WORKS

1. Earthwork
2. Roads & Surfacing
3. Pipes
4. Concrete
5. Rehabilitation of Existing Structures
6. Waterproofing
7. Metal Works
8. Woodwork
9. Painting

PART IV – CIVIL WORKS

1. Earthwork

Table of Content

IV-1-A EARTHWORK (GENERAL)

IV-1-A-1 Description

This work shall consist of clearing and grubbing, stripping, excavating, removing unsuitable soil, filling, backfilling and other specified works related to the earthwork.

IV-1-A-2 General Requirements

Prior to any excavation the Contractor shall submit detailed drawings showing the locations of the excavations to the Engineer for approval.

Excavation in streets and roads shall not be commenced without written approval from the Engineer.

Before the commencement of any earthworks or demolition the sites shall be surveyed as necessary in conjunction with the Engineer's representative to establish existing ground levels.

The Contractor shall not start any earthwork before getting the Engineer's approval on the cross sections.

The Contractor shall correct all disapproved cross sections and resubmit them for approval.

The Contractor shall excavate refill and restore in advance of his program such trial holes as he may require for determining the nature of the subsoil and the location of existing underground services and obstructions.

The Contractor shall ensure that there are no pipes, cables, mains or other services or properties, which may be disturbed or damaged by its use. He will take all protections not to damage these services and restore these services if damaged on his own expense.

IV-1-A-2-1 Explosives

The Contractor shall at all times take every possible precaution and comply with the Explosives Laws of Lebanon and regulations relating to the handling, transporting, storing 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's Representative. The Contractor shall also provide a special proper store for explosives in accordance with local regulations and shall provide experienced men with valid blasting licenses for handling explosives to the satisfaction of the Engineer and the authorities concerned.

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 the relevant authorities and shall be restricted to such hours and conditions as may be prescribed. Blasting within 10 meters of existing water mains will not be permitted.

Blasting shall be carried out so as not 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 a method statement including details of the intended drilling patterns, depths of holes, the amounts of explosives at each location, and the method or sequence of setting off what he proposes to use.

IV-1-A-2-2 Clearing & Grubbing

IV-1-A-2-2-1 Description

This work shall consist of clearing, grubbing, removing and disposing of all vegetation and debris within the limits specified. This work shall also include the preservation from injury or defacement of all vegetation and objects designated to remain.

IV-1-A-2-2-2 General Requirements

The areas to be cleared and grubbed shall be as shown on the Plans, as designated in the Specifications or as directed by the Engineer. The Engineer will designate all trees, shrubs, plants and other things to remain. The Contractor shall preserve all things designated to remain.

Before carrying out work, 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, which may be affected by the works.

In the case of wayleaves for pipelines, the boundaries of the wayleave will be defined by the Employer and the Contractor shall provide, erect, and maintain in position from commencement to final completion of the Works, in every section substantial timber stakes or similar approved markers not less than 1.5m high indicating the position of the boundary at 100 m or other such intervals as the Engineer may direct. In the event of any boundary or survey mark established for the purpose of land title being disturbed or displaced the Contractor shall forthwith replace the beacon. Where necessary the Contractor shall employ the services of an approved licensed surveyor for the purpose of setting out boundaries.

Before beginning clearance in any area the Contractor shall give seven days written notice of his intention to the Engineer who will determine the extent and limits of such clearance.

All surface objects and all trees, stumps, roots, sod and vegetable matter, other protruding obstructions, not designated to remain shall be cleared and grubbed.

Within the limits of clearing and grubbing, all stumps, roots 4 cm in diameter or larger, buried logs, and all other objectionable material shall be removed 90 cm below the existing ground surface or sub-grade, whichever is deeper.

Except in areas to be excavated, stump holes and other holes from which obstructions are removed shall be backfilled with suitable material and compacted to 90% of Maximum Dry Density.

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

Topsoil shall be set aside for re-use or disposal off site as directed by the Engineer.

Trees to be removed shall be uprooted or cut down as near to the ground level as possible.

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

Materials resulted from site clearance shall be disposed by the Contractor to a place approved by the Engineer.

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

In the case of wayleaves for pipelines, dam and the lake, the Contractor shall preserve as far as practicable all grass and other vegetation outside the limits of trenches and permanent works and shall

not unnecessarily destroy crops or any vegetation whose removal would not be essential to his operations.

The Contractor shall take 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.

IV-1-B EXCAVATION

IV-1-B-1 Excavation in General

IV-1-B-1-1 Description

This work shall consist of all excavation for structures, lake, dam, chutes, canals, pipelines, trenches, gallery, culverts, headwalls, basins, gravel traps, manholes, inlets, retaining walls, roadways and other specified works.

IV-1-B-1-2 Classification

All excavation will be classified as one of the following :

a. Common Excavation Common excavation consists of the excavation and disposal of all materials of whatever character encountered in the work except rock.

b. Rock Excavation Rock is defined as a sound and solid mass, layer, or ledge of mineral matter in place and of such hardness and texture that it cannot be effectively loosened or broken down by ripping in a single pass with a late model tractor-mounted hydraulic ripper equipped with one digging point of standard manufacturer's design adequately sized for use with and propelled by a crawler-type tractor rated between 385 and 410 net flywheel horsepower operating in low gear.

   In areas where the use of the ripper described above is impracticable, rock is defined as sound material of such hardness and texture that it cannot be loosened or broken down by a manual-drifting pick. Boulders and detached stones having a volume of 0.75 cubic meters or more shall be classified as rock.

c. Unclassified Excavation "Unclassified Excavation" shall be that volume of excavation consisting of the removal of all materials regardless of their physical properties.

IV-1-B-1-3 General Requirements

Excavation shall be made in open cutting unless tunneling 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.

The Contractor shall ensure the stability and safety of excavations and shall take all measures necessary to ensure that no collapse or subsidence occurs.

Except where described in the contract or permitted under the Contract excavation shall not be battered. 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, waling, poling boards, sheeting, bracing, and the like.

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.

IV-1-B-1-3-1 Excavation in Excess

In the event of unsuitable ground being encountered at formation level or if the formation is damaged or allowed to deteriorate, the Contractor shall forthwith inform the Engineer. The Contractor shall excavate to such extra depth and refill with compacted granular or other approved fill or Class " D" concrete as the Engineer may require. With respect to the side face of any excavation against which concrete or other work will be in contact the Engineer may require that the net dimensions of the work be increased.

If any part of any excavation is in error excavated deeper and/ or wider than what is required, the extra depth and/or width shall be filled with Class " D" concrete or compacted granular or other approved fill to the original formation level and/or dimensions as the Engineer directs on the contractor's expense.

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

IV-1-B-1-3-2 Excavated Materials Suitable for Re-use

No excavated material suitable for re-use shall be removed without the approval of the Engineer.

During excavation, the Contractor shall ensure that all material suitable 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.

During excavation, the Contractor shall ensure that all granular or other approved material suitable for filling around and over pipes shall be kept separate and re-used 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 topsoil shall be stripped and separately stacked.

IV-1-B-1-3-3 Damages Caused to the Surface of Roads

Where the surface of the road damaged either by the concentration of traffic caused by an open excavation, by subsidence or other causes arising from the operations of the Contractor. The Contractor shall permanently reinstate the whole of the surface to its original condition.

IV-1-B-1-3-4 Safety of Excavations

The Contractor shall ensure that excavation and reinstatement are maintained in a safe condition and shall take immediate action to remedy any deterioration, which renders the works unsafe. If in the opinion of the Engineer any excavation or reinstatement is in a dangerous condition the Contractor shall immediately remedy the defect. Should the contractor fail to carry at the reinstatement promptly, the work may be carried out by others at the Contractor's expense.

IV-1-B-1-3-5 Mechanical Excavation

Mechanical excavation shall be deployed only if the subsoil is suitable and only in such manner which will allow adequate support of the equipments.

IV-1-B-2 Excavation For Structures

IV-1-B-2-1 Description

This work shall consist of all excavation for structures, gravel traps, chutes, basins, culverts, headwalls, manholes, inlets, retaining walls or other structures, and other excavation for structures.

IV-1-B-2-2 General Requirements

The Contractor shall notify the Engineer a sufficient time in advance of the beginning of any excavation for structures which so that the Engineer may observe the cross-sectional elevations and measurements taken of the existing ground and structure. Any materials removed or excavated before these measurements have been taken and approved by the Engineer will not be paid for.

The foundation shall be excavated to the outlines of the footings as shown on the Plans or as required by the Engineer and shall be of sufficient size to permit the placing of the full width and lengths of the footings shown with full horizontal beds. Rounded or undercut corners and edges of footing will not be permitted.

The excavation shall be carried out to the elevation shown on the plans or as established by the Engineer. No concrete shall be poured prior to the approval on the excavation by the Engineer. Over depth excavation below the footing elevation if not approved by the Engineer and over width excavation beyond the lateral limits for footings as shown on the Plans or directed by the Engineer, shall be backfilled with the same class of concrete designated for the footing and shall be poured monolithically with the footing. No payments shall be made for unauthorized excess excavations and concrete backfill. The Contractor alone shall bear the additional expense.

Where rock bottom is secured the excavation shall be done in such manner as to allow the solid rock to be exposed and prepared in horizontal beds or properly serrated for receiving the concrete. All loose and disintegrated rock and thin strata shall be removed.

Where unstable material or other unsuitable material is encountered below foundation elevation of reinforced concrete structures, the Contractor, at the direction of the Engineer, shall excavate such unstable material and replace with suitable and stable backfill material or blinding concrete as shown on the Plans or directed by the Engineer. The foundation stabilization, necessary depth of excavation and suitability of the proposed backfill material shall be approved by the Engineer prior to the Work.

Suitable and practically watertight cofferdams, or other watertight equipment and materials to maintain a water free excavation shall be used whenever water-bearing strata are encountered above the elevation of the bottom of the excavation. They shall be sufficiently large to give easy access to all parts of the foundation form and shall be of dimensions not less than those for which payment for excavation is made and shall be deemed included in the excavation price.

If cofferdams have to be used, then cofferdams shall be constructed so as to keep the excavations free from earth, water, ice, or snow and to permit the excavations to be carried to depths up to 1m below the foundation elevations shown on the plans. They shall be substantially braced in all directions, and of such construction as will permit them to be pumped free of water, and kept free until the concrete has been placed. They shall be such that leakage can be kept out of the concrete or masonry. Unless otherwise shown on the plans or agreed upon with the Engineer, cofferdams and all sheeting or bracing shall be removed after the completion of the concrete or masonry. When the bottom is of sandy or porous material which will not, in the opinion of the Engineer, permit the footing to be poured in the dry, it shall be sealed with concrete so that it may be pumped dry. The cement content water / cement ratio and the maximum coarse aggregate size will be submitted to the Engineer prior to the work. A seal course shall not be used unless shown on the Plans or authorized in writing by the Engineer. If in the opinion of the Engineer, the necessity for a seal course is due to inadequate or improper cofferdam construction, he may order the removal and/or reconstruction of the cofferdam, or permit the placing of a seal course at the Contractor's expense. Other satisfactory methods of sealing out the water may be approved.

After the seal course has set, the cofferdam shall be cleared of water and the work completed in the dry. When weighted cribs are employed and the weight utilized to overcome partially the hydrostatic pressure acting against the bottom of the foundation seal, special anchorage such as dowels or keys shall be provided to transfer the entire weight of the crib into the foundation seal. Cofferdams shall be constructed so as to protect green concrete against the damage from a sudden rising of the stream and to prevent damage to the foundation by erosion.

The provision of dewatering equipment and all operations required to maintain a water free excavation shall be carried out and considered subsidiary to the items of structural excavation.

Maintenance of natural waterways and allowance for the passage of surface water during construction is the Contractor's responsibility and any damage occurring in this respect shall be corrected at the Contractor's expense.

IV-1-B-2-2-1 Excavation for Foundations of Structures

The Contractor shall give sufficient notice and sufficient time in advance to the Engineer to enable him to inspect and approve foundations in advance of placement of the permanent work. The Engineer may withdraw his approval if work is not commenced within 48 hours or the formation is subsequently allowed to deteriorate.

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

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

Surfaces against which permanent works are to be placed shall be kept free of oil, water, mud or any material.

No concrete or other materials shall be placed until formations have been approved. Adequate notice shall be given to the Engineer to enable him to examine the formation.

IV-1-B-2-2-2 Rock Surfaces Under Concrete Structures

IV-B-2-2-2-1 Concrete Placed Directly on Rock

Rock under concrete structures shall be prepared by picking, barring, and wedging or other methods which will lease the rock in as sound a condition as may reasonably be expected according to the rock quality.

Rock surfaces shall be thoroughly cleaned by compressed air and water jet or such means as the Engineer may direct before concrete is placed.

IV-B-2-2-2-2 Concrete Placed on Capping Layer

Where instructed the rock excavation shall be taken down to a depth of 1.0 m below the underside of the structure and the excavation backfilled with capping materials to the required formation level.

Capping material shall be an approved granular material.

The material shall be compacted in 150mm layers to achieve a density of not less than 95% maximum dry density determined by the Moisture - Density curve of the material.

IV-1-B-3 Excavation For Pipes

IV-1-B-3-1 Description

This work shall consist of excavation for pipes laying to the required line and grade.

IV-1-B-3-2 General Requirements

Except by permission of the Engineer, the maximum length of open trench shall be 150 meters or the distance necessary to accommodate the amount of pipe installed in a single day, whichever is the greater.

The width of trench excavation shall be the minimum required for efficient working after allowance has been made for any timbering and strutting, and shall not exceed the widths described, unless otherwise specified, in the drawings or by the Engineer. The trench width shall be equal to 1.5 the

internal diameter of the pipe plus 30 cm. If the trench width is exceeded, the Contractor shall provide additional bedding, another type of bedding as shown on Plans or approved by the Engineer, at no additional cost.

When excavating in unstable material, the Contractor shall use sheeting and bracing to prevent caving or collapse of the sidewalls. He shall take all possible precautions to prevent cave-ins, and he shall be fully responsible for the safety of the workmen and the protection of the work. If the ground-water table is above the bottom of the trench, or if water from any source is encountered, the Contractor shall employ all necessary means including but not limited to sheeting, bracing and the removal of water by pumping in order to maintain a water free excavation.

Unless otherwise specified, in the drawings or by the Engineer trenches in rock for pipes up to l00 mm bore shall be excavated to provide a minimum clearance of 100 mm around the outside of the pipe and joints. Unless otherwise specified, in the drawings or by the Engineer for pipes exceeding 100 mm bore the minimum clearance shall be increased to 150 mm.

If unsuitable material is encountered upon which the bedding material or pipe is to be placed, this unsuitable material shall be removed to a depth ordered by the Engineer and replaced with suitable material approved by the Engineer.

Where the trench is in rock or rocky ground the Contractor shall excavate the pipe trench to a depth of 150 mm below the invert of the pipe and refill with an approved sand fill.

The materials for re-use excavated from trenches shall be stockpiled at the sides of the trench except where this would obstruct any road or footpath and prevent the passage of traffic or pedestrians.

IV-1-C NATURE AND ORIGIN OF THE FILLING MATERIALS FOR THE RESRVOIR AND THE DAM WORKS

IV-1-C-1 General Requirements

The fill and backfill materials intended for the construction of various works, shall be supplied by the Contractor and shall be obtained from extraction sites which were submitted and approved by the Engineer and must comply with the Technical Specifications.

The approval of the Engineer does not relieve the Contractor from his responsibility as to the quality of materials furnished to the site.

Any change as to the source of the material will have to be approved by the Engineer. Furthermore, the Engineer has the right during the works, to ask for a change of source in the event the quality is not in compliance with the present specifications.

All material must satisfy the French Standard AFNOR and DTU documents, American Standards ASTM or British Standards BS.

IV-1-C-2 General Points on the Quarries

A part of the filling material are originating from limestone quarries for which the Contractor shall search for in surrounding areas.

The limestone quarries must be homogeneous, joint free with convenient stratification and little bedding to obtain material of the required quality.

The Engineer will accept or refuse the quarries in a period of 15 days following the Contractor's request. The Contractor must, at his own expense carry out several drillings and trenches that will enable the Engineer to appreciate the quality of the proposed materials.

The cost of searching for a quarry deposits and testing it shall be on the expenses of the Contractor.

If during the works, the excavated material no longer conforms to the required quality, or if the volume of the usable proportion is insufficient, the Contractor must, at his own expense, search for other sites conforming to the specifications.

IV-1-C-3 Quality and Preparation of Borrowed Materials

IV-1-C-3-1 Norms

All materials shall satisfy with AFNOR, DIN, ASTM or BS norms.

IV-1-C-3-2 Material Gradation and Quality

The size and gradation of the material listed below shall comply with the specifications and must satisfy all the necessary requirement in selecting the best-fitted gradations.

IV-1-C-3-2-1 High Quality Rock Paving For Dam Downstream Facing Protection

IV-C-3-2-1-1 General

These rocks are intended for the construction of the dam and must have sufficient hardness. Therefore, if dumped in bulk and/or manipulated by mechanical equipment, they do not break. These rocks shall also be homogeneous, cracks free, and clean as much as possible and have weathering resistance i.e. against water, air, etc…

Deval hardness must be greater than 20 and Los Angeles coefficient lower than 30. Rock's gradation shall be regular and avoiding flat or elongated shapes in aggregates.

IV-C-3-2-1-2 Gradation

The maximum rock size placed in a particular layer must not be greater than 80% of the theoretical thickness of that layer after compaction.

On the other hand, gradation of rocks shall confirm with the following limits:

Dimensions of sieve opening		Percent weight passing through sieve openings
AFNOR	Sieve hole diameter (mm)	
-	800	100
-	630	80 to 100
55	315	25 to 55
51	125	5 to 25
45	31,5	Less than 5

The above gradation must be respected in any volume of 10 m^3.

IV-1-C-3-2-2 Filter materials

IV-C-3-2-2-1 General

The filter material shall be obtained by sieving natural sand coming from sand quarries in the surrounding areas. This area of materials semi-permeable is intended to reduce infiltration caused by joint gaps, disorder or any flexible sheet gap.

Their gradation must be as regular as possible, stable against water and air, and containing clean rock materials clear from any kind of contamination, clay, or any organic material. Again, avoid as much as possible any flat and/or elongated aggregates.

IV-C-3-2-2-2 Gradation

The maximum rock size in each layer must not be greater than 80% of the theoretical thickness of that layer after compaction.

On the other hand, rock gradation shall confirm to the following limits:

Dimensions of sieve opening		Percent weight passing through sieve openings
AFNOR	Sieve hole diameter (mm)	
50	80	100
38	5	35 to 100
35	2,5	20 to 50
29	0,63	10 to 25
20	0,08	Less than 10

The above gradation must be respected inside any volume of 10 m^3.

IV-1-C-3-2-3 Draining and Transition Material

This layer is constituted of well-graded small rocks. Their gradation must be as regular as possible, stable against water and air, and containing clean rock materials clear from any kind of contamination, clay, or any organic material. And should not contain any aggregates of flat and/or elongated shapes.

The maximum rock size in each layer must not be greater than 80% of the theoretical thickness of that layer after compaction.

On the other hand, rock gradation shall confirm to the following limits:

Dimensions of sieve opening		Percent weight passing through sieve openings
AFNOR	Sieve hole diameter (mm)	
-	200,00	100
49	62,50	50 to 100
36	30	35 to 40
39	6,00	15 to 30
34	2	0 to 15
23	0,16	0

The above gradation must be respected inside any volume of 10 m3.

IV-1-C-3-2-4 Selected Fill Materials

The maximum percent weight passing the 100 mm sieve must be lower than 40%, passing the 5 mm sieve must be lower than 15% and passing the 0.1 mm must be lower than 5%.

The above gradation must be respected in any volume of 5 m^3.

IV-1-C-3-3 Rockfill, Drain and Filter Materials

Rockfill, drains and filter materials must have sufficient hardness to be discharged in bulk and manipulated by power machines without being broken or disintegrated. They must be homogeneous, freeze resistant, unaffected by water or air and shouldn't contain earthly or organic components, nor soluble components. Rockfill and drain materials shall have a minimum specific weight of 2.6 t/m3.

IV-1-D FILL AND BACKFILL WORKS

IV-1-D-1 Fill and Backfill in General

IV-1-D-1-1 Description

This work shall consist of all fill and backfill for structures, lake, dam, chutes, canals, pipelines, gallery, culverts, headwalls, basins, manholes, inlets, retaining walls, roadways and other specified works.

IV-1-D-1-2 General Requirements

Backfilling whether around foundations or in pipe trenches 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 re-laid.

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.

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

Temporary reinstatement and permanent reinstatement of all surfaces affected by the operations of the Contractor shall be carried out and maintained to the satisfaction of the Engineer and the responsible authority or owner.

Temporary reinstatement shall be carried out immediately after the trenches are backfilled.

Permanent reinstatement shall not be carried out until the ground has consolidated completely. 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 make the reinstatement good to the approval of the Engineer or responsible authority.

Unless otherwise specified in the drawings or by the Engineer, for the purposes of temporary and permanent reinstatement in bitumen and 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 surfaced roads shall be carried out to the approval of the relevant authority.

The responsible authority shall have the right to carry out permanent reinstatement at the Contractor’s expense.

Excavation in open ground shall be reinstated to the condition in which the ground 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 backfilling has been thoroughly consolidated, the topsoil shall be re-laid rolled and planted with grass or other vegetation as-directed by the Engineer as may be necessary, and watered until the grass has become well established. Should the planting fail it shall be replanted as required until a satisfactory growth is obtained.

If at any time any reinstatement deteriorates, the Contractor shall restore it to a proper condition immediately.

Should the Contractor not remedy the defect to the Engineer's satisfaction, the Employer and/or the responsible authority at the Contractor’s expense may undertake all necessary remedy of the defects.

All trees, shrubs and plants shall be carefully transplanted and shall be returned to their original location after the refilling of the excavations. Return of old or mature trees may be waived in cases where the age of the tree makes return impracticable.

Topsoil shall be carefully set aside and replaced at the surface of the backfilling.

The trenches shall be refilled and rammed solid as specified in the Contract and shall not be topped up above the original surface level to allow for settlement.

If any trench becomes dangerous the Engineer may call upon the Contractor for its reinstatement at three hours' notice and failing this to have the work done by others at the Contractor's expense.

IV-1-D-2 Compaction of Earthwork

IV-1-D-2-1 Description

This work shall consist of the compaction of earthwork by rolling or tamping or any combination of these methods in accordance with the requirements for the Moisture Range and Type, designated or ordered by the Engineer.

IV-1-D-2-2 General Requirements

Each layer shall be compacted to a density between 90 and 95 % of the maximum density (for lake and dam refer to paragraph 2-D-.4). This maximum density shall be determined by the AASHTO T 180-93, method D test or equivalent Standard Test for cohesive soils, by the ASTM D 2049 test or equivalent Standard Test for cohesionless soils.

In case where borderline materials are encountered, both the following tests will be utilized and the test which results in the higher laboratory maximum density shall be used as a standard to which the field density is compared.

Each layer of earth fill shall be compacted by approved tamping or sheep foot rollers, pneumatic tired rollers, or other mechanical means as requested by the Engineer and depending on the soil nature.

At locations where it would be impractical because of inaccessibility to use such compacting equipment, fill layers shall be compacted to the specified requirements by hand directed compaction equipment.

Whenever fill is placed adjacent to structures or at locations where it is not practicable to use a roller, the fill material shall be well tamped by the use of mechanical rammers or tampers. Each layer shall be compacted to a density equal to or greater than obtained under the above rolling procedure for the type of compaction designated. Each layer must be approved by the Engineer before the next layer is placed. When the quantity of work is small, a hand tamper may be used with the permission of the Engineer.

At the time of compaction, the moisture content of the soil shall be within the moisture range as defined in the Test Methods. When the moisture content of the soil does not fall within the required moisture range, water shall be added and thoroughly mixed with the soil, by approved methods or the material shall be aerated, whichever is needed to adjust the soil to the specified moisture content before compaction.

IV-1-D-3 Backfill for Structures

IV-1-D-3-1 Description

This work shall consist of backfilling with suitable material uniformly distributed and thoroughly compacted, around structures, chutes, culverts, manholes, retaining walls, gravel traps or other structures.

IV-1-D-3-2 General Requirements

Structure backfill shall not be placed until the structure has been inspected by the Engineer and approved for backfilling. In general, no structure shall be subjected to the pressures of backfilling or to live loads until three(3) days after the expiration of the period designated for the removal of forms. At the direction of the Engineer, this period may be extended if subnormal curing conditions exist. Backfill, placed around culverts, abutments and piers, or a particular structure as designed by the Engineer, shall be deposited on both sides to approximately reach the same elevation at the same time. Special care shall be taken to prevent any wedging action against the structure. The slopes bounding the excavation shall be stepped when necessary, to prevent such wedge action. Whenever backfill is placed in back of or over arches, culverts or rigid frames, the fill shall be first placed midway between the ends of the structure, working equally both ways from the center of the structure toward the ends.

The material shall be placed in layers and compacted by means of suitable equipment, or by tamping with mechanical tampers or hand tampers. Each layer shall be compacted to a density equal to or greater than ninety five (95) percent of the maximum density determined by AASHTO T 180-74, Method D. Each successive layer shall contain only that amount of material which will ensure proper compaction, but in no case shall any layer be greater than fifteen (15) centimeters (compacted measurement) in thickness. When backfilling and compacting around retaining walls, extreme care shall be exercised to prevent forward movement of the wall. If not specified elsewhere or indicated on the plans, the backfill around structures shall be completed to the level of the original ground or to the finished ground level, whichever is lower unless otherwise specified.

IV-1-D-4 Execution Of Rocks Paving For The Downstream Facing Protection

The rocks in accordance with the required specifications for this particular zone shall be placed to the maximum possible position in its final locations. The finishing of the rock paving demands individual arrangement of each block by means of a heavy mechanical equipment for the big blocks and by hand equipment for the smaller blocks, in a manner that a linear and plain surface is obtained free of any knobs.

If necessary, in some locations that the contractor should proceed with filling the voids between the big blocks by hand width a smaller size in order to obtain a consistent and compact volume.

The contractor must take all necessary measures to ensure safety and security of the site while paving with big chunks of rocks.

IV-1-D-5 Riprap

IV-1-D-5-1 Description

This work shall consist of furnishing and placing one (1) or more layers of riprap on a prepared surface in conformity with the lines, grades, thicknesses and typical cross sections shown on the plans or established by the Engineer.

IV-1-D-5-2 Materials

Riprap shall consist of aggregate, from hard, durable, quarried or natural stone having an apparent specific gravity of not less than 2.4, and the absorption shall not exceed 5 percent. The stone shall be free of weak laminations and cleavages, and shall not disintegrate on exposure to water or weathering. The aggregate shall be round or angular.

IV-1-D-5-3 Gradation Requirements

Small size riprap gradation shall be as follows.

SIEVE OPENING SIZE IN CENTIMETERS	PERCENT PASSING (By weight)
20	100
15	50
10	0

Medium size riprap gradation shall be as follows.

SIEVE OPENING SIZE IN CENTIMETERS	PERCENT PASSING (By weight)
40	100
30	50
20	0

IV-1-D-5-4 Construction Requirements

IV-1-D-5-4-1 Sub-grade Preparation

The Contractor shall, as a part of this work and prior to the delivery of the material for the riprap, prepare the bed surface by sprinkling, blading, rolling, and lightly scarifying where necessary, until the proper slope is obtained for pipe riprap placing. However, in the process of shaping the bed, the originally compacted crust or top portion of the bed shall be disturbed as little as possible. When completed and ready for riprap construction, the bed shall be well compacted, smooth, hard and uniform, all irregularities having been bladed out and rolled down.

IV-1-D-5-4-2 Placing

The material shall be so handled as to avoid segregation. If an aggregate spreader causes segregation in the material or leaves ridges or other objectionable marks on the surface, which cannot be eliminated easily or prevented by adjustment of the spreader operation, the use of such spreader shall be discontinued and replaced.. All segregated material shall be removed and replaced with well-graded material. No “skin” patching shall be permitted.

Riprap shall be placed to grade in a manner to insure that the larger rock fragments are uniformly distributed and the smaller rock fragments serve to fill the spaces between the larger rock fragments in such a manner as will result in well-keyed, densely placed, uniform layers of riprap of the specified thickness. Hand placing will be required only to the extent necessary to secure the results specified above.

All humps and depressions and thickness deficiencies exceeding the specified tolerance of five (5) centimeters shall be corrected by removing the defective work or by adding new material as directed by the Engineer.

IV-1-E TESTS ON MATERIALS

IV-1-E-1 Test Methods

IV-1-E-1-1 Moisture - Density Curve Test

A Moisture - Density Curve (AASHTO T 180-93, Method D or equivalent standard) will be determined for each type of soil to be used in the construction of the work to determine the Maximum Density, the Optimum Moisture content and the Moisture Range required of the soil for satisfactory

compaction. The field density and actual Moisture Content of the compacted embankment shall be determined by field curves according to AASHTO

T 191 or equivalent standard.

IV-1-E-1-1-1 Maximum Density

The Maximum Dry Density as determined by the Moisture-Density curve shall be the density to which the Field Density is referred for comparison or percentage for each type of soil used in the work.

IV-1-E-1-1-2 Optimum Moisture

The Optimum shall be the moisture content corresponding to the Maximum Density on the Moisture - Density curve.

IV-1-E-1-1-3 Moisture Range

The Moisture Range shall be the limits of moisture content of each type of soil with the Optimum moisture as a reference.

IV-1-E-1-1-4 Field Density

The Field Density shall be the density of the compacted embankment determined by the Field Density Test.

IV-1-E-1-1-5 Moisture Content

It is the percentage of moisture in the specimen based on oven dry mass of soil. The Moisture Content shall be the actual moisture content of the soil in the compacted embankment at the time of compaction.

IV-1-E-1-2 Relative Density Test

For cohesionless free draining soils for which impact compaction will not produce a well-defined Moisture - Density relationship curve, the test for the Relative Density of Cohesionless Soils (ASTM D2049 or equivalent Standard) shall be used to determine the relative density.

Relative density is defined as the state of compactness of a soil with respect to the loosest and densest states at which it can be placed by the laboratory procedures described in ASTM D2049 or equivalent Standard. The Field Density and actual Moisture Content of the compacted embankment shall be determined by field tests according to AASHTO T 191-93 or T 238-86 or equivalent Standards.

IV-1-E-1-2-1 Relative Density

The Relative Density as determined by the Relative Density Test shall be the standard to which the Field Density is referred for comparison for each type of cohesionless soil used in the Work.

IV-1-E-1-2-2 Field Density

The Field Density shall be the density of the compacted embankment determined by the Field Density Test.

IV-1-E-1-2-3 Moisture Content

It is the percentage of moisture in the specimen based on oven dry mass of soil. The Moisture Content shall be the actual moisture content of the soil in the compacted embankment at the time of compaction.

IV-1-E-2 General Prescriptions For The Reservoir and Dam Fill works

The Contractor shall keep a constant control on the works by mean of tests, at his own expenses and under the control of the Engineer. The Contractor can eventually subcontract the tests to specialised laboratories.

The Contractor has to submit to the approval of the Engineer, the laboratories as well as the list of test to subcontract.

The approval of the Engineer to undertake the tests in these laboratories does not relieve Contractor from his responsibility.

If during the works, the Engineer is not satisfied by the progress of the tests, as planned by the Contractor, he can ask the Contractor to modify his arrangements.

The necessary tests and samplings should be undertaken according to the recommendations of the French, American and British specifications or others agreed by the Engineer.

The Contractor remains fully responsible as to the stability of the works he will have executed.

The Contractor must take into consideration all the necessary expenses for:

- The samplings (undertaken by a specialised laboratory).
- The transportation of the samplings from the field to the laboratory.
- The conservation and treatment of the samples before the tests.
- The tests and the result reports.
- The equipment and the functioning of the field laboratory under the control of the Engineer are at the expense of the Contractor, who shall take them into consideration in his prices.

The number and types of tests listed below and before are provided for the control and good execution of the Contract. They are totally at the expense of the Contractor. The Engineer could require other tests or increase the frequency of the tests and their number, if doubting their conformity with the specifications. The Contractor will have to undertake these supplementary tests, without any complain or price revision.

IV-1-E-3 Tests On Borrowed Materials

All borrow material for the the reservoir and the dam will be tested before and after use. The Contractor must submit to the Engineer as soon as possible and at the latest 15 days after the date of the notification of the contract, a detailed program and the time schedule for the tests.

IV-1-E-3-1 Tests And Sampling Relative To The Rockfill, Filters And Drains Materials

d. During the works

The necessary tests for the approval of the filters, drains and rockfill materials are:

- Sieve analysis
- Specific gravity
- Compression tests on original rocky materials
- Freeze resistance
- Compaction test: shall comply with the experimental trial test executed previously on the filter, drain and rock material towards the number of passes verses the settlement necessary to give the required maximum dry density.

It is necessary to undertake a series of tests per 100 m^3 of filter or drain and 500 m^3 for rockfill materials, but in no case less than one sample per day for each type of material.

IV-1-F WIRE ENCLOSED RIPRAP (GABIONS)

IV-1-F-1 Description

This work shall consist of the installation of wire-enclosed riprap (gabions) in the locations designated on the plans.

IV-1-F-2 Materials

IV-1-F-2-1 Aggregate

Aggregate for riprap shall be hard, durable, quarried or natural stone having an apparent specific gravity of not less than 2.4, and the absorption shall not exceed 5 percent. The stone shall be free of weak laminations and cleavages, and shall not disintegrate on exposure to water or weathering. The aggregate shall be round or angular and not less than 95 percent of the stone shall be retained on a screen having 3-inch square openings.

IV-1-F-2-2 Gabions and Mattress

Gabions and mattresses shall be constructed of double twisted wire mesh. The wire mesh shall be made of galvanised steel wire. The tensile strength of the wire before manufacturing shall be in the range of 38-50 kg/mm2 according to BS 1052/80.

The minimum zinc coating of the wire shall be 240 gr/m2 of uncoated wire surface according to BS 443/82, the mesh type for gabions and mattresses as follows:

	Gabions	Mattresses
Mesh Type	8 x 10	6 x 8
Mesh Wire	Ø 2.70 mm	Ø 2.20 mm
Selvedge Wire	Ø 3.40 mm	Ø 2.70 mm
Lacing Wire	Ø 220 mm	Ø 2.00 mm

Selvedge, tie and lacing wire shall meet the same strength and coating requirements specified above for wire used in the wire mesh.

Selvedge, tie, and connection wire shall meet the same strength and coating requirements specified above for wire used in the wire mesh.

IV-1-F-2-3 Fabrication

The wire mesh shall be double twisted to form hexagonal openings of uniform size. The mesh shall be fabricated in such a manner as to be non-ravelling. Non-ravelling is defined as the ability to resist pulling apart at any of the twists or connections forming the mesh when a single wire strand in a section is cut.

Gabions shall be fabricated so the sides, ends, lid, and diaphragms can be assembled at the construction site into rectangular baskets of the specified size. Gabions shall be of single unit construction-base, lid, ends, and sides shall be either woven into a single unit or one edge of these members connected to the base section of the gabion in a manner that strength and flexibility at the point of connection is at least equal to that of the mesh.

Where the length of the gabion exceeds its horizontal width, the gabion shall be equally divided by diaphragms of the same mesh and gauge as the body of the gabions, into cells the length of which does not exceed the horizontal width. The gabion shall be furnished with the necessary diaphragms secured in proper position on the base in a manner that no additional tying at this junction will be necessary.

All perimeter edges of the mesh forming the gabion shall be securely clip bound or selvedges so that the joints formed by tying the selvedge have at least the same strength as the body of the mesh.

Tie and connection wire shall be supplied in sufficient quantity to securely fasten all edges of the gabion and diaphragms and to provide for at least four cross connecting wires in each cell whose height is equal to the width and at least two cross connecting wires in each cell whose height is one-half the width of the gabion. Cross connecting wires will not be required when the height of the cell is one-third the width of the gabion. Tie and connection wire shall meet the same strength and coating specifications as the wire used in the mesh, except that it may be as much as two gages smaller.

IV-1-F-2-4 Installation

The gabions shall be placed on a smooth foundation. Final line and grade shall be approved by the Engineer.

Each gabion unit shall be assembled by binding together all vertical edges with a continuous piece of connecting wire. Empty gabion units shall be set to line and grade as shown on the plans or as directed by the Engineer. Wire ties, or connecting wire shall be used to join the units together in the same manner as described above for assembling. Internal tie wires shall be uniformly spaced and securely fastened in each cell of the structure.

A standard fence stretcher, chain fall, or iron rod may be used to stretch the wire baskets and hold alignment.

The gabions shall be filled with stone carefully placed by hand or machine to assure alignment and avoid bulges with a minimum of voids. Alternate placing of rock and connection wires shall be performed until the gabion is filled. After a gabion has been filled, the lid shall be bent over until it meets the sides and edges. The lid shall then be secured to the sides, ends and diaphragms with the wire ties or connecting wire in the manner described above for assembling.

PART IV – CIVIL WORKS

2. Roads & Surfacing

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IV-2-A AGGREGATES

IV-2-A-1 Sources of Materials

All aggregates for use in the construction of the base course shall be obtained only from sources approved by the Engineer. The quarry pits or quarry extracted gravel shall be in all cases approved by the Engineer.

The Contractor shall determine the location, suitability and quantity of material available as well as the cost and the amount of work required to obtain the material available.

The Contractor shall provide the Engineer prior to the schedule beginning operations with a complete statement of the origin and composition of all stone and/or gravel aggregates to be used in the work. All materials shall comply with the specified requirements for the various aggregates.

The locating and the manufacture of aggregates which will meet the requirements of the specifications are the sole responsibility of the Contractor.

The approval of the Engineer shall in no way relieve the Contractor of the responsibility of producing aggregates which meet the specifications.

No aggregate producing equipment shall be put into operation prior to the approval of the equipment by the Engineer. If after the equipment is put into operation it fails to perform as proposed, the Contractor shall provide additional approved equipment or replace the original equipment with more suitable equipment, as may be directed by the Engineer.

IV-2-A-2 Testing

In order to ascertain the properties of all aggregate materials, the Contractor shall submit, for approval by the Engineer, test certificates from an approved testing laboratory for all materials intended for incorporation in the work prior to starting quarry or pit operations.

Representative samples for such testing shall be taken by the Contractor, at his expense, in the presence of the Engineer, and duplicate samples shall be submitted to the Engineer for future reference.

The Contractor may, if approved by the Engineer, conduct the necessary tests in the laboratory. The tests shall be conducted in the presence of the Engineer. The resume of the qualifications must be submitted to and approved by the Engineer prior to any testing operations.

This testing, whether performed at an approved testing laboratory or in the project laboratory, shall be solely the Contractor's responsibility and will be at the Contractor's expense.

IV-2-A-3 Approval and Inspection

All sources of materials shall be approved by the Engineer prior to procuring or processing material from such sources. Test certificates obtained by the Contractor or performed by the Contractor at his expense are intended to assist the Contractor in his estimate of the location, extent, and quantities which will comply with the specifications when properly processed, and will no way obviate the need for further testing by the Engineer. Only materials from approved sources shall be processed for incorporation into the work. Approval of specific sources of materials shall not be construed as final approval and acceptance of materials from such sources.

All processed materials shall be tested and approved before being stored on the site or incorporated in the work and may be inspected and tested at any time during the progress of their preparation and use. Questionable materials shall not be unloaded and incorporated with materials previously approved and accepted. If however, the grading and quality of the material delivered to the site do not conform to the grading and quality as previously inspected and tested, or do not comply with the specifications,

the Engineer reserves the right to reject such materials at the site of the work. Only materials conforming to the requirements of the specifications shall be used in the work.

Samples must meet all test requirements. The Contractor shall permit the Engineer to inspect any and all material used or to be used at any time during or after its preparation, or while being used during the process of the work or after the work has been completed. All such materials not complying with the required specifications, whether in place or not, shall be rejected and shall be removed promptly from the work. The Contractor shall supply, or arrange with any producer or manufacturer to supply, all necessary materials, labor, tools and equipment for such inspection.

IV-2-A-4 Storage

Materials shall be stored so as to insure preservation of their specified quality and fitness for the work. They shall be placed on hard, clean surfaces and, when required by the Engineer, they shall be placed under cover. Stored materials shall be located as to facilitate prompt inspection and control. Private property shall not be used for storage purposes without written consent of the owner or lessee and payment to him, if necessary.

The center of the storage area shall be elevated and sloped to the sides so as to provide proper drainage of excess moisture. The material shall be stored in such a way to prevent segregation and coning to insure proper control of gradations and moisture. Course aggregate storage piles shall be built-up in layers not exceeding one (1) meter. The height of a stockpile shall be limited to a maximum of five (5) meters.

The equipment and methods used for stockpiling aggregates and for removing aggregates from the stockpiles must be approved by the Engineer and shall be such that no detrimental degradation of the aggregate will result and no appreciable amount of foreign material will be incorporated into the aggregate.

IV-2-B AGGREGATE BASE COURSE

IV-2-B-1 Description

This work shall consist of furnishing and placing well graded aggregate afggregate base course in successive layers of 15 cm, including additives if required, on a prepared surface in accordance with the specifications, and in conformity with the lines, grades, thicknesses and typical cross sections given in the drawings or as required by the Engineer.

IV-2-B-2 Materials

Materials shall conform to the requirements for the class of “Aggregate Base Course”, specified on the plans or directed by the Engineer. All aggregates for base course shall consist of clean, tough, durable, sharp angle fragments free of any excess of thin or elongated pieces, and reasonably free of soft, disintegrated or decomposed stone, dirt or other deleterious matter.

IV-2-B-2-1 Physical Requirements

All base course aggregate shall conform to the following physical requirements:

Loss of Sodium Sulfate Soundness	
Test	10 percent maximum
Loss of Magnesium Sulfate Soundness	
Test	12 percent maximum
Loss by Abrasion Test	35 percent maximum
Thin and Elongated Pieces, by	

Weight (larger than 1-inch, thickness less than 1/5 length	5 percent
Friable Particles	0.25 percent maximum

IV-2-B-2-2 Aggregate Base Course - Class A

Material for class A shall consist of crushed gravel or stone fragments conforming to the following requirements:

AASHTO SIEVE	PERCENT PASSING
2 inch	100
1-½ inch	90 - 100
3/4 inch	50 - 80
No. 4	25 - 45
No. 40	10 - 20
No. 200	2 - 7

- Sand equivalent: 40% minimum (Aggregates passing through AASHTO SIEVE no: 4)
- Regular graded aggregate curve
- Loss of abrasion test: 40 % maximum

IV-2-B-2-3 Aggregate Base Course - Class B

Materials for Class B shall be crushed rock or crushed gravel conforming to the following grading requirements:

AASHTO SIEVE	PERCENT PASSING
2-½ inch	100
2 inch	90 - 100
1-½ inch	35 - 70
1 inch	0 - 15
½ inch	0 - 5

Fine materials for Class B base course shall be quarry screenings or natural material and of suitable binding quality as approved by the Engineer. The material shall be free from foreign or organic matter, dirt, shale, clay and clay lumps, or other deleterious matter and shall conform to the following requirements :

AASHTO SIEVE	PERCENT PASSING
3/8 inch	100
No. 4	85 - 100
No. 100	10 - 30
Plasticity Index (AASHTO T 90)	6 maximum
Sand Equivalent (AASHTO T 176)	30 minimum

The combined material shall consist of a mixture of all aggregates uniformly graded from course to fine to conform to the following gradation requirements:

AASHTO SIEVE	PERCENT PASSING
2-½ inch	100
2 inch	90 - 100
1-½ inch	60 - 90
1 inch	42 - 77

3/4 inch	35 - 70
½ inch	25 - 60
No. 4	15 - 40
No. 10	10 - 26
No. 40	5 - 15
No. 200	2 - 9

IV-2-B-2-4 Aggregate Base Course - Class C

Material for Class C base course shall consist of uniform mixture of crushed rock and/or gravel with sand, silt and clay, conforming to the following requirements

AASHTO SIEVE	PERCENT PASSING
1-1/2 inch	100
1 inch	60 -100
3/4 inch	55 - 85
No. 4	35 - 60
No. 10	25 - 50
No. 40	15 - 30
No. 200	8 - 15

The grading is based on aggregates of uniform specific gravity, and the percentage passing the various sieves are subject to correction by the Engineer, when aggregates of varying specific gravities are used.

Liquid Limit (AASHTO T 89)	25 maximum
Plasticity Index (AASHTO T 90)	4-8 maximum
Sand Equivalent (AASHTO T 176)	50 minimum

IV-2-B-2-5 Aggregate Base Course Class D

- Density >2.45 kg/dm^3
- Resistance of compression = 500 kg/cm^2 on a test cube 7cm x 7cm x 7cm
- Sand equivalent: 40 min (Aggregates passing through AASHTO SIEVE No. 4)

AASHTO SIEVE	PERCENT PASSING
2 inch	100
1 inch	40 95
1/2 inch	40 - 75
No. 4	30 - 60
No. 10	20 - 60
No. 40	15 - 30
No. 200	5 - 20

IV-2-B-2-6 Acceptance

The aggregate will be accepted immediately following mixing, based on periodic samples taken. When the aggregate is a total aggregate, it may be accepted at the crusher. Acceptance of the material by the Engineer does not constitute acceptance of the base course, only that the material is approved for use in the base course.

IV-2-B-2-7 Construction Requirements

IV-2-B-2-7-1 Subgrade Preparation

The subgrade shall be well compacted, smooth, hard and uniform, all irregularities having been bladed out and rolled down for construction.

At all special grade control points, the subgrade shall be leveled to such depth that the proper thickness of base course may be constructed flush with the existing surface. The transition from normal to special section shall be of sufficient length to present no abrupt or noticeable change of grade and shall be excavated in accordance with the grades and lines shown on the plans or directed by the Engineer.

IV-2-B-2-8 Maintenance of Subgrade

The roadbed being prepared shall be maintained true to cross section and grade until the base course is completed.

IV-2-B-2-9 Method of Construction

IV-2-B-2-9-1 Combining Aggregates and Water

Aggregates for base course shall be combined into a uniform mixture and water added either in a central mixing plant or by watering in a manner approved by the Engineer, before final placement of the material. When binder is to be added, if approved by the Engineer, it may be combined with the aggregate base by thoroughly mixing separate quantities of binder and aggregate base or it may be combined in the central mixing plant. Adding binder by spreading it will not be permitted.

The moisture added to the aggregates shall be that required, as designated by the Engineer, to obtain the specified density thereby preparing an aggregate completely ready for compaction after spreading on the subgrade. In no case will the wetting of aggregates in stockpiles or trucks be permitted.

IV-2-B-2-9-2 Spreading and Combining Aggregates

Unless otherwise specified, aggregate for base courses shall be delivered to the roadbed as a uniform mixture and shall be placed on the site prepared subgrade, in a uniform layer. Spreading shall be done by means of approved self-propelled stone spreaders, distributing the material to the required width and loose thickness.

The material shall be so handled, as to avoid segregation. If an aggregate spreader causes segregation in the material, or leaves ridges or other objectionable marks on the surface which cannot be eliminated easily or prevented by adjustment of the spreader operation, the use of such spreader shall be discontinued and replaced. All segregated material shall be removed and replaced with well-graded material. No “skin” patching shall be permitted.

IV-2-B-2-9-3 Compaction

Immediately after placing, the base course material shall be compacted as required by AASHTO or equivalent.

The surface of the finished base course will be tested with a three (3) meter straightedge at selected locations. The variation of the surface from the testing straightedge between any two (2) contacts with the surface shall at no point exceed ten (10) millimeters, unless otherwise specified, when placed on or parallel to the centerline or when placed perpendicular to the centerline.

IV-2-B-2-9-4 Maintenance

Following the construction of the aggregate base course, the compacted course shall be maintained by the Contractor at his expense. The Contractor shall, broom and maintain the base, keeping it free from raveling and other defects until such time as the bituminous prime or other surface is applied.

IV-2-C BITUMINOUS BASE COURSE

IV-2-C-1 Description

This Work shall consist of aggregate and bituminous material mixed in a central plant, and spread and compacted on an approved primed subgrade in accordance with the specifications and in conformity with the lines, grades, thickness and typical cross sections or as required by the Engineer.

IV-2-C-2 Materials

IV-2-C-2-1 Mineral Aggregates

Mineral aggregates for "Bituminous Base Course" shall consist of course aggregates, fine aggregates, and filler material, if required, all complying with the following requirements :

a. Course aggregate which is the material retained on an AASHTO No. 4 sieve, shall consist of crushed rock or crushed gravel. It shall be clean, hard, tough, durable and sound, and shall be of uniform quality and free from decomposed stone, organic matter, shale, clay, lumps and other deleterious substances.

   The course aggregate shall be free of excess of flat elongated pieces (in no case more than ten (10) percent) and shall be of such character that when coated with asphalt shall pass a stripping test performed in accordance with AASHTO T 182.

   Crushed gravel for use as course aggregate shall consist of the product obtained by crushing material that has first been screened in such a manner that not less than ninety (90) percent of the material to be crushed is retained on a Standard AASHTO No. 3/8 inch sieve, The amount of crushing of gravel shall be regulated so that at least ninety (90) percent by weight of the material retained on an AASHTO No. 4 sieve shall consist of pieces- with at least one (1) mechanically fractured face, and when tested for stability of bituminous mix shows satisfactory stability. Course aggregate, used for "Bituminous Base Course" only, may be uncrushed angular material which meets the angular and other requirements herein.

b. Fine aggregates shall consist of that portion of the total aggregate that passes a standard AASHTO No. 4 sieve and after crushing at least eighty-five (85) percent by weight of the material passing the AASHTO No. 4 sieve and retained on the AASHTO No. 10 sieve, shall consist of pieces having at least one (1) mechanical fractured face. Should natural material passing the AASHTO No. 4 sieve be included in the mixture, this material shall be fed to the dryer as a separate aggregate and the amount used shall be so limited that the mixture of fine aggregates will contain not less than twenty-five (25) percent by weight of the crushed aggregates.

c. When the combined grading of the course and fine aggregates is deficient in material passing the AASHTO No. 200 sieve and depending on laboratory analysis of the Asphalt Institute, mineral filler shall be added as approved by the Engineer. Mineral filler shall consist of finely divided mineral matter such as rock dust including limestone dust, slag dust, hydrated lime, hydraulic cement, or other approved mineral matter. At the time of use it shall be sufficiently dry to flow freely and essentially free from agglomerations. Filler material shall conform to the requirements of AASHTO M-17. Gradation requirements as follows :

SIEVE	PERCENT PASSING (BY WEIGHT)
No. 40	100
No. 200	75 - 100

d. The combined mineral aggregate shall meet the quality requirements and, shall conform to the following physical requirements :

Lost by abrasion test: 30% max.

Sand equivalent: 50% min. (Aggregates passing through AASHTO SIEVE No. 4)

Absorbtion shall not exceed 2%

Gradation requirements are as follows:

AASHTO SIEVE SIZE	PERCENT PASSING
3/4 inch	100
1/2 inch	75 - 100
3/8 inch	60 - 85
No. 4	35 - 50
No. 8	20 - 35
No 30	10 - 16
No. 50	6 - 16
No. 100	4 - 12
No. 200	2 - 8

IV-2-C-2-2 Asphalts

Asphalt for "Bituminous Base Course" shall be petroleum asphalt cement, grade 40-50 penetration, conforming to the requirements in the following table :

The asphalt shall be prepared by the refining of petroleum. It shall be uniform in character and shall not foam when heated to 176.7 degrees C

Specifications for Asphalt Cements

GENERAL REQUIREMENTS	Unit	Asphalt	Asphalt	Asphalt
Penetration,				
25° C 100 grams	0.1 mm	40-50	60-70	80-100
5 seconds				
Flash point in ° C				
(Cleveland open				
cup)	°C	232	232	232
Thin film				
test (weight loss in % at t = 163 ° C during 5 hours)	%	1	1	1
Ductility : at 25°C	cm	100	100	100
Solubility in Trichloroethylene, percent	%	99.5	99.5	99.5

IV-2-C-2-3 Job-Mix

At least thirty (30) days prior to the date the Contractor intends to begin production of the Bituminous Base Course, and after receiving approval of the aggregates from the Engineer and after the delivery on site, of the asphalt specified for "Bituminous Base Course", the Contractor shall make written request for the approved job-mix formula from the Engineer.

The job-mix formula will be prepared by the Contractor, under the supervision of the Engineer, in the project laboratory.

The job-mix formula shall combine the mineral aggregates and asphalt in such proportion as to produce a mixture conforming to the following composition limits by weight :

	PERCENT
Total Mineral Aggregates	94 - 95
Asphaltic Binder	5 - 6 (of the total volume)

When tested according to the Marshall Method, the bituminous mixture shall conform to the following requirements :

Stability (kgs)	500 minimum
Flow (mm)	4mm & Less than 4 mm
Voids in total mix (percent)	3 - 6

All trial mixes shall be prepared and tested by the Contractor and results are given to the Engineer. The Marshall Test procedure will be used to determine the percentage of liquid asphalt that is to be incorporated into the mixture. For the same reasons, a low asphalt content in the mix is detrimental. The job-mix formula will therefore provide for as high as possible for a mix designed by the Marshall Test procedure. The mix formula will also take into consideration the absorption of asphalt into the aggregates. Thus, for calculations for voids, the adjusted bulk specific gravity of the Marshall specimens, adjusted for the portion of asphalt lost by absorption, shall be used.

The gradation of the combined aggregate, including the mineral filler shall be within the limits specified in the specifications for the Class of "Bituminous Base Course" to be used. The Engineer may vary the specified limits where he deems it necessary, on the basis of the Marshall tests, to obtain optimum stability and life of the completed mix.

Upon receiving the job-mix formula, approved by the Engineer, the Contractor shall adjust his plant to proportion the individual aggregates, mineral filler and asphalt to produce a final mix that, when compared to the job-mix formula, shall be within the following limits:

MAXIMUM VARIATIONS OF PERCENTAGE OF MATERIALS PASSING		
AASHTO No. 10 and less	± 2	percent
AASHTO No. 4 and larger	± 5	percent

The Engineer will test the mix periodically and, if necessary, direct the Contractor to readjust the plant to maintain conformity of the job-mix formula. If, during production, the grading of the aggregates alters, the mix shall be redesigned and the plant readjusted as outlined above.

The assistance of the Engineer in the preparation of the job mix formula in no way relieves the Contractor of the responsibility of producing a bituminous mixture meeting the requirements of the specifications.

IV-2-C-2-4 Equipment

Equipment used by the Contractor must fit with his obligations and results to fulfill to best the works within the technical specifications and as directed by the Engineer. Trucks used for hauling bituminous mixtures shall have tight, clean, smooth metal beds which have been thinly coated with a minimum amount of paraffin oil, lime solution, or other approved material to prevent the mixture from adhering to the beds. When required by the Engineer, each vehicle shall be equipped with a canvas cover or other suitable material of such size as to protect the mixture from the weather.

IV-2-C-3 Construction Requirements

Rolling equipment shall be self-propelled. The wheels on the rollers shall be equipped with adjustable scrapers and the rollers shall have water tanks and sprinkling apparatus which shall be used to keep the wheels wet and prevent the surface material from sticking.

Weights of two-axle tandem steel rollers, three-axle tandem steel rollers, three-wheel steel rollers, and self-propelled pneumatic-tired rollers and the total weight of the pneumatic-tired roller shall be as directed by the Engineer.

IV-2-C-3-1 Preparation of Asphalt Cement

Asphalt cement shall be heated within a temperature range of 135 degrees °C to 163 degrees °C at the time of mixing. Asphalt cement spreading will be made at 135 degrees °C. Asphalt cement received at temperatures in excess of 163°C but not exceeding 191°C may be used.

IV-2-C-3-2 Preparation of Mineral Aggregates

Each aggregate ingredient shall be heated and dried at such temperatures that the temperature as recorded in the hot fines bin after screening shall not exceed 163 degrees C. If the aggregates contain sufficient moisture to cause foaming in the mixture or their temperature is in excess of 163 degrees C, they shall be removed from the bins and returned to the respective stockpiles. Immediately after heating, the aggregate or aggregates shall be and conveyed into separate bins ready for batching and mixing with bituminous material.

IV-2-C-3-3 Preparation of Bituminous Mixture

Dried aggregate as specified for bituminous construction and prepared as prescribed above shall be combined in the plant in the proportionate amounts as approved. Asphalt cement shall be introduced into the mixture in the proportionate amount determined, all according to the job-mix formula.

IV-2-C-3-4 Preparation of subgrade or existing surface

Prior to the placing of the mixture, when designated on the plans or directed by the Engineer, a prime coat shall be applied to the subgrade or existing surface in accordance with the standards specified in Section “Bituminous Prime Coat”.

IV-2-C-3-5 Placing of the Mixture

The bituminous mixtures shall be spread and finished true to crown and grade by the automatically controlled bituminous paver. Bituminous mixtures may be spread and finished by hand methods only where machine methods are impractical as determined by the Engineer.

The automatically controlled paver shall spread the bituminous mixtures without tearing the surface and shall strike a finish that is smooth, true to cross section, uniform in density and texture and free from hollows, transverse corrugations and other irregularities.

The paver shall be operated at a speed which will give the best results for the type of paver being used and which coordinates satisfactorily with the rate of delivery of the mixture to the paver so as to provide a uniform rate of placement without intermittent operation of the paver.

Bituminous mixtures, except on leveling courses, shall be spread so that, after rolling, the nominal thickness of the compacted bituminous material will fit with the finished level as given on shop drawings.

The maximum thickness for layers may be increased slightly when such increase is more adaptable to total pavement thickness with the permission of the Project Engineer.

IV-2-C-3-6 Compaction of Mixtures

After spreading and strike-off and as soon as the mix conditions permit the rolling to be performed without excessive shoving or tearing, the mixture shall be thoroughly and uniformly compacted.

Rolling shall not be prolonged till cracks appear. Rollers shall be of the steel wheel and/or pneumatic-tire type and shall be in good condition, capable of reversing without backlash, and shall be operated at speeds slow enough to avoid displacement of the bituminous mixture. The number and weight of

rollers (between 10 T and 12 T) shall be sufficient to compact the mixture to the required density while it is still in a workable condition. The use of equipment which results in excessive crushing of the aggregate will not be permitted.

Initial or breakdown rolling shall be done by means of either a tandem power steel roller or a three (3) wheel power steel roller. Rolling shall begin as soon as the mixture bear the roller without undue displacement. Rolling shall be longitudinally, beginning at the low side of the spread of material and proceeding toward the high side, overlapping on successive trips by at least one-half (1/2) the width of the rear wheels. Alternate trips of the roller shall be of slightly different lengths.

The motion of the roller shall at all times be slow enough to avoid displacement of the mixture and the speed of the roller controlled. To prevent adhesion of the mixture to the rollers, the wheels of the rollers shall be kept properly moistened with water, but an excess of water will not be permitted.

The initial or breakdown rolling shall be followed by rolling with a pneumatic-tired roller. Final compaction and finish rolling shall be done by means of a tandem power steel roller unless otherwise designated. When the specified density is not obtained, changes in size and/or number of rollers shall be made as corrective measures to satisfy the density requirement .

Rollers shall be operated by competent and experienced roller men and shall be kept in operation continuously, if necessary, so that all parts of the pavement will receive substantially equal compaction at the time desired. The Engineer will order the mixing plant to cease operation at any time proper rolling is not being performed.

The road density requirements shall be equal to or greater than ninety-six (97) percent of the Marshall Density of each day's production.

Any mixture that becomes loose, broken, mixed with foreign material, or which is in any way defective in finish or density, or which does not comply in all other respects with the requirements of the specifications shall be removed replaced with suitable material, and finished in accordance with the specifications.

IV-2-C-3-7 Joints

Joints between old and new pavements or between successive days work shall be made so as to insure thorough and continuous bond between the old and new mixtures. Transverse construction joints in previously laid material shall be constructed by cutting the material back vertically for its full depth so as to expose a fresh surface.

Before placing the fresh mixture against a cut joint or again old pavement, the contact surface shall be sprayed or painted with a thin uniform coat. Where a finishing machine is used, the longitudinal joint shall be made by over lapping the screed on the previously laid material for a width of at least three (3) centimeters and depositing a sufficient amount of mixture so that the joint forced will be smooth end tight.

IV-2-C-3-8 Introduction of Fresh Mixture

The Contractor shall protect all sections of newly compacted mixture from traffic until they have hardened properly.

IV-2-C-3-9 Surface Tolerances

The surface will be tested with a four (4) meter straightedge by the Engineer at selected locations. The variation of the surface from the testing edge of the straightedge between any two (2) contacts with the surface shall at no point exceed six (6) millimeters when placed on or parallel to the centerline or six (6) millimeters when placed perpendicular to the centerline of the roadway. The top of the base shall not vary from the required elevation by more than five (5) millimeters. All humps and depressions exceeding the specified tolerance shall be corrected by removing the defective Work and replacing it with new material as directed by the Engineer.

IV-2-C-3-10 Weather Limitations

Hot asphaltic mixtures shall be placed only when the air temperature is five (5) degrees C or above and less than 40 degrees C, and when the weather is not foggy or rainy and when the existing surface is free from moisture.

IV-2-D BITUMINOUS PRIME COAT

IV-2-D-1 Description

This work shall consist of applying a liquid asphalt prime coat on previously constructed aggregate base course before spreading the bituminous base course, and as otherwise specified; in accordance with the specifications, and in conformity with the lines shown on the plans or established by the Engineer.

IV-2-D-2 Material

Medium-curing cutback asphalt shall consist of an asphaltic base fluxed with suitable petroleum distillates. The product shall be free of water and shall conform to all the requirements of Grade MC-0/MC-1 as shown in the following Tables.

CHARACTERISTICS	MC-0	MC-1	MC-2	MC-3	MC-4	MC-5
Flash point (Open Tag), degrees C - Minimum	38	38	66	66	66	66
Furol Viscosity at 25 degrees C, seconds	75-150					
Furol Viscosity at 50 degrees C, seconds		75-150				
Furol Viscosity at 60 degrees C, seconds			100-200	250-500		
Furol Viscosity at 82 degrees C, seconds					125-250	300-600
Max % of water in volume	0.1	0.1	0.1	0.1	0.1	0.1
Distillation						
Distillate (percent of total distillate to 360 degrees C - Max	50	40	33	27	22	18
To 225° degrees C	0-25	0-20	0-10	0-5	-	-
To 260° degrees C	40-70	25-65	15-55	5-40	0-30	0-20
To 316° degrees C	75-93	70-90	60-87	55-85	40-80	20-75
Texts on Residue form Distillation: Penetration, 25 degree C,						
100 grams, 5 seconds	120-300	120-300	120-300	120-300	120-300	120-300
Ductility, 25 degrees C in centimeters (minimum)	50	50	50	50	50	50
Solubility in carbon Tetrachloride, percent (minimum)	99	99	99	99	99	99
General Requirements	The materials shall be free from water					

	Temperature for Mixing	Temperature for Spraying
Asphalt Cement		
40 - 50	150 - 160	-
60 - 70	135 - 162	140 - 165
80 - 100	135 - 163	140 - 165
Prime Coat		
MC - 0	10 - 49	11 - 60

MC - 1	27 - 66	47 - 85
MC - 2	47 - 82	60 - 102
MC - 3	66 - 93	80 - 121
MC - 4	79 - 107	88 - 130
MC - 5	105 - 121	105 - 143

IV-2-D-3 Construction Requirements

It shall be the Contractor's sole responsibility to maintain the surface in an approved condition, conforming to the required grades and sections. Any defects which may develop shall be immediately corrected at the Contractor's expense.

Equipment used by the Contractor must fit with these obligations and results to fulfill to best the works within the technical specifications and as directed by the Engineer.

Prior to the application of the bituminous material, all loose materials shall be removed from the surface and the surface shall be cleaned by means of approved mechanical sweepers or blowers and/or hand brooms, until it is as free from dust as is deemed practicable. If deemed necessary by the Engineer, the cleaned surface shall be given a light application of water and allowed to dry to a surface-dry condition before the bituminous material is applied. No traffic shall be permitted on the surface after it has been prepared to receive the bituminous material.

IV-2-D-3-1 Application of the Prime

Medium-curing cutback asphalt, Grade MC-0 / MC-1, shall be applied at the rate as directed by the Engineer, by approved pressure distributors operated by skilled workmen. The spray nozzles and spray bar shall be adjusted and frequently checked so that uniform distribution is insured. Spraying shall cease immediately upon any clogging or interference of any nozzles, and corrective measures taken before spraying is resumed.

Hand sprays will be approved only for priming small patches or inaccessible areas that cannot be primed by normal operation of the distributor.

Care shall be taken that application of bituminous material at the junction of spreads is not in excess of the specified amount. Any excess shall be squeezed from the surface when ordered by the Engineer. Any skipped areas or recognized deficiencies shall be corrected by means of approved hand sprays.

IV-2-D-3-2 Rate of Application

The rate of application for prime material is 1000g/m², the Engineer may alter the previously established rate so the Contractor shall, prior to the time he intends to begin his priming operation, prepare a test section of an approved length for the determination of the rate of application for the prime coat.

IV-2-D-3-3 Protection of Adjacent Structures

When bituminous materials are being applied, the surfaces of all structures and any roadway appurtenances shall be protected in a manner approved by the Engineer to prevent them from being splattered with bituminous material or marred by equipment operation. In the event that any appurtenances become splattered or marred, the Contractor shall at his own expense, remove all traces of bituminous materials, and repair all damage and leave the appurtenances in an approved condition.

IV-2-D-3-4 Blotting

If deemed necessary by the Engineer after the bituminous material has been applied for forty-eight (48) hours under favorable conditions and the prime coat has not dried sufficiently that it will not be damaged by traffic, a light application of aggregate shall be applied. The blotter material shall be a clean fine sand, chat sand, or other material as approved by the Engineer. Blotting material shall be

applied sparingly on only the areas that have not dried. Blotting of the prime coat shall be done only when directed by the Engineer. Normally, additional time shall be allowed for drying of the prime coat when in the opinion of the Engineer this procedure does not seriously delay subsequent operations.

IV-2-D-3-5 Maintenance of Prime Coat

The Contractor shall maintain the prime coat treatment, and the bituminous base of the subgrade or base course intact until it shall have been covered by the surface course. Any area where the prime coat has been damaged by traffic or by the Contractor's operations, shall be cleaned of all defective base course or subgrade repaired to the satisfaction of the Engineer and the maintenance and repair of the prime coat and the underlying subgrade shall be done at the Contractor's expense.

IV-2-D-3-6 Traffic Control

The Contractor shall provide detours for the traveling public and for operational use in areas where priming is being done. Where no convenient detour can be made available, the Contractor shall provide traffic control and the priming operation shall be confined to a part of the roadway.

IV-2-D-3-7 Weather and Temperature Limitations

Application of prime coat shall be performed only when the surface is dry, when the atmospheric temperature is above ten (10) degrees °C and less than 40°C, and when the weather is not foggy or rainy.

PART IV – CIVIL WORKS

3. Pipes

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IV-3-A GENERAL REQUIREMENTS

IV-3-A-1 Installation of Pipes

IV-3-A-1-1 General

Do not commence with excavation of any part of the project until a full supply of pipes and fittings are available on site.

During pipe laying, all precautions shall be taken to avoid ingress inside the pipe of any foreign material, dirt or soil.

Pipes are lowered down in the trench with adequate equipment and shall be placed in the right position for the jointing purposes.

Pipes and special pieces and apparatus shall be brought down in the trench carefully avoiding any sudden shocks or falls, etc.

Placing and installing the pipes shall be performed by experienced laborers.

During the course of the work(s) executed within the water table it is necessary to keep the trench bottom dry during the placing of gravel or sand pipe bedding.

Temporary wedges shall be placed to get the proper alignment and at the change of direction. These wedges shall be made of compacted earth heaps or wood pieces. Using stone wedges will not be allowed.

Pipe ends shall be temporarily closed with wooden, plastic flanges or with special pieces during the stopping of the works.

IV-3-A-1-2 Excavation For Pipe Trench

- Do not commence with excavation at any part of the project until a full supply of pipes and fittings is available on site.
- Excavation width shall be enough to utilize pipes installations and in no conditions less than 600 mms or less than pipe diameter OD + 150 mms from both sides.
- Excavated material shall be deposited 400 mms away from the edge of trench.
- Stabilizing trench walls, either by battering or shoring.
- Clear the edges of the excavations of lumps of rocks or clods of earth.
- Trench bottoms are prepared at every point to the depth indicated on the longitudinal profile. Unless otherwise specified.
- Excessive trench width and depth in excavation shall not be considered for additional payment. Unless otherwise specified by the Engineer.
- Excavation with battered sides will not be permitted within 4 meters from any building or structure and the edge of excavation.
- Excavate to 100 mms below pipe invert level with additional 1/5 of the pipe size for diameters over 500 mms, and to 250 mm below pipe invert level in rock excavations.
- The thickness of the pipe bedding shall be 10 cm under the pipe + 1/10 cm of the nominal diameter of the pipe or as shown on the Drawings.
- Preparation pipe beds by remove unstable material, rock projection, boulders and hard spots and replace with approved compacted material.

IV-3-A-1-3 Pipe Installation In Trench

- All pipes and fittings are to be present on site and ready for installation by well trained and professional crew.
- Examine and clean all pipes and fittings before installation. Damaged items are to be removed immediately from site for repair or dispose.
- Incase of pipe cutting, use slitting disc type cutter or an air operated saw for lager pipes. After cutting and before assembly, it is essential to fillet or chamfer the edge of the cut with file. Finally restore the protective coating on the pipe areas affected by the cutting operations if applicable.
- Install pipes to the invert level indicated on the longitudinal profile using proper survey tools.
- Pipes shall not be dragged along the trench bottom.
- Ensure inner and outer coatings are not damaged and pipe is clean.
- Examine the pipe visually against any break of hair cracks, bends, bumps or deflection along pipe length.
- Use proper ropes and protected hooks when handling pipes.
- Use pieces of soft wood when leveling the pipes in the trench. Do not use stones, bricks, etc… this may damage the coating.
- Install joints as specified on the drawings and where needed and as directed by the Engineer.
- Do not leave ends of pipes opened if installations stopped. Use tight lids supplied by manufacture.
- Whenever part or section of pipes, not exceeding 500 meters, is installed in the trench. Submit a written request for pressure testing before backfilling and compacting the pipe trenches.
- Each portion of pipeline shall be a full pipe span, as much as possible in order to reduce to the minimum pipe joints.
- Pipes and fittings laid in trench shall have at least the minimum cover stated on the Drawings.
- Long radius curves in buried pipelines shall be negotiated by deflections taken up in one or more pipes. The deflection in pipeline shall not exceed the specified limits.
- Provide a minimum cover of 900 mm on top of the pipe and shall be laid with a minimum gradient of 1 in 500.

IV-3-A-1-4 Backfilling Pipe Trenches

IV-3-A-3-1-4-1 Initial backfil1

Use only selected fill, sand or other approved material complying with following:

Standard Sieve No. #	% Passing
3/4	100
# 4	25-100
# 16	10-75
# 40	5-30
# 100	3-10
# 200	0-5

Initial backfill shall be used as bedding material underneath the pipe. Use the same for filling around the pipe and to 200 mms layer above the top of the pipe compacted to 95 % of proctor maximum dry

density by a compacting machines suitable for trench width. Material around the pipes shall be compacted with proper tools as recommended by the manufacture, and as directed by the Engineer.

IV-3-A-3-1-4-2 Main backfill

Material excavated from the trenches and are suitable for compaction can be used as main backfill over pipes, otherwise use material with a maximum size of 50 mms, well graded and suitable for compaction and approved by the Engineer.

- Backfill shall be laid and well compacted in layers not exceeding 300 mms thick.
- Do not use heavy compactors over pipe trench until there is 600 mms of cover over the pipe.
- If the cove over the top of the pipe is less than 650 mms, use concrete in casement as specified on the drawings and directed by the Engineer.
- When backfilling to pipes with concrete beds and surrounds, do start backfilling before 24 hours or allow heavy compactors and traffic over the pipes before 72 hours of placing concrete.
- Use temporary crossing over the trench to prevent damaging the pipes.

IV-3-A-2 Cutting Pipes

IV-3-A-2-1 General

Before cutting the pipe, it is essential to measure the external diameter at the cutting point with a circumference tape or compass calipers, to check that it is compatible with the intended coupling joint dimensions.

Use hacksaws, manually operated wheel cutter or pipe cutting machine as per manufacturer's instructions. Prepare ends according to the type of joint used and follow manufacturer's recommendations. Take care not to damage lining of other type pipes associated with main pipes. Repair on site, minor damage, if permitted.

After making the cut, and before assembly, it is essential to fettle the edges of the cut with a file.

IV-3-A-2-2 Ductile Iron Pipes

Ductile iron pipes shall only be cut with an approved mechanical pipe cutter in conformity with the pipe manufacturer's recommendations. The use of an oxyacetylene flame cutter will not be permitted. The edges of the cut together with those parts of the pipes from which the coating has been removed shall be given two coats of bituminous paint and the internal lining repaired. When the cut pipe is to be inserted in a "Tyton" type joint it shall be beveled for 10mm at 30° to pipe the axis.

IV-3-A-2-3 Polyethylene

Pipes shall be cut with an approved mechanical pipe cutter and in conformity with pipe manufacturer's recommendations. Where the cut end of the pipe is to be incorporated in a joint the pipe shall be turned down to the correct diameter required for forming the joint by an approved mechanical turning machine. The length of turning shall be sufficient to enable the joint to be properly made The ends of the pipe shall be accurately beveled by mechanical means to the dimensions specified in the manufacturers recommendations.

IV-3-A-3 Concrete Surrounding Pipes

IV-3-A-3-1 General

All concrete works shall comply with the appropriate requirements of PART II, section 4: CONCRETE.

Concrete surround shall be broken at all pipe joints to retain flexibility in the pipeline in case of shallow pipes, except for pipes crossing under watercourse, the concrete surrounding shall be continuous and rigid.

When pipes intersect with other utilities, the pipe shall be surrounded with concrete, the joints at such crossing shall be ridged.

All concrete encasements shall not be executed without the prior approval of the Engineer.

IV-3-A-3-2 Materials

Concrete bedding: cast in situ CLASS "D".

Concrete encasement with reinforcement: cast in situ CLASS "B"

IV-3-A-3-3 Placing Concrete

After placing pipe place concrete in trench and thoroughly work under the pipe to provide solid and uniform bedding.

Place the balance of concrete on both sides of the pipe simultaneously.

Introduce vertical construction joints in concrete beds, surroundings etc. at the face of pipe joint with compressible board and finish to profile of concrete and pipe. Fill any gap left in concrete with approved resilient material.

IV-3-A-4 restoration of surface

1. General: Proceed with surface restoration as soon as other practicable works is completed, but in no case more than 10 days after backfilling of the trench and other excavated areas and complete within a further 20 days.
2. Restoration of asphalt, concrete and/or gravel pavements are to be brought back to its original thickness and materials to match the existing pavement. Material and workmanship are to be in according to the local municipality requirements or as directed by the Engineer.
3. Restoration of pavement: Repave to match existing pavements in quality, shape, size and level to a uniform surface finish with existing surface.
4. Restoration of grassed areas: After backfilling is compacted and brought to the bottom of the previous top soil level, spread approved fertilized soil over affected area and seed, Continue fertilizing and watering until grass is restored to its former condition.
5. Restoration of unsurfaced area: Bring backfill to natural ground level, well compacted and distributed evenly.

IV-3-A-5 General Terms and Conditions

IV-3-A-5-1 Scope

This specification covers requirements for polyethylene piping system (pipe and fittings) for the supply of water under pressure intended for human consumption both above ground and in buried pipe applications.

IV-3-A-5-2 Engineered and Approved Plans

Construction shall be performed in accordance with engineered construction plans for the work prepared under the direction of a Professional Engineer.

IV-3-A-5-3 Referenced Standards

In absence of Lebanese standard specifications The most recent ISO standards or European Norms (EN12202) apply.

IV-3-A-5-4 Inspections

All work shall be inspected by an Authorized Representative of the Owner who shall have the authority to halt construction if, in his opinion, these specifications or standard construction practices are not being followed. Whenever any portion of these specifications is violated, the Project Engineer or his Authorized Representative, shall, by written notice, order further construction to cease until all deficiencies are corrected. A copy of the order shall be filed with the Contractor's license application for future review. If the deficiencies are not corrected, performance shall be required of the Contractor's surety.

IV-3-A-5-5 Warranty and Acceptances

The Contractor shall warrant all work to be free from defects in workmanship and materials for a period of [one year] from the date of completion of all construction. If work meets these specifications, a letter of acceptance, subject to the [one year] warranty period, shall be given at the time of Completion. A final acceptance letter shall be given upon final inspection at the end of the [one year] warranty period, provided the work still complies with these specifications. In the event deficiencies are discovered during the warranty period, they shall be corrected b the Contractor without additional charge to the owner before final acceptance. During the warranty period, the Project Engineer shall determine if warranty repairs or replacement work shall be performed by the Contractor. The decision of the Project Engineer shall be binding upon the Contractor.

IV-3-A-5-6 Qualification of Manufacturers

The Manufacturer shall have manufacturing and quality control facilities capable of producing and assuring the quality of the pipe and fittings required by these specifications. The manufacturer's production facilities shall be open for inspection by the Owner or his Authorized representative. Qualified Manufacturers shall be approved by the Project Engineer.

IV-3-A-5-7 Approved Manufacturers

Manufacturers must be pre-qualified and pre-approved by the Project Engineer. Products from unapproved manufacturers are prohibited.

IV-3-A-6 Polyethylene Pipes / Fittings

IV-3-A-6-1 Raw Materials

The polyethylene compounds used in the manufacture of products furnished under this specification shall be made from compounded pellets obtained by the addition of the correct type and amount of carbon black and necessary antioxidants and other additives to protect the pipe during extrusion and assure the life expectancy of the pipe. Pipe produced by the addition of black masterbatch to polyethylene is strictly forbidden. The compound material shall comply with the requirements as specified in EN 12201-Part 1.

Typical material properties as described by the Raw Material Supplier brochure shall be submitted to the project engineer for analysis and verification of compliance. These properties are not to be misconstrued as specification minimums.

All Raw Material used shall be approved and certified Pipe Grade Material for the transportation of potable water.

IV-3-A-6-2 Polyethylene Pipe

IV-3-A-3-6-2-1 Pipe Coil

Pipes with OD up to 110 mm shall be supplied in coils where the inside diameter of the coil is 30 times OD. Pressure pipes with OD of 110mm and above shall be supplied in straight lengths. When needed special pipe length can be supplied with the approval between purchaser and manufacturer.

IV-3-A-3-6-2-2 Marking of Pipe

All pipes shall bear permanent identification markings that will remain legible during normal handling, storage, installation, and service life and that have been applied in a manner that will not reduce the strength nor otherwise damage the products. The marking shall not initiate any defects in the surface and will not provide leakage channels when elastomeric gasket compression fittings are used to make joints. Both hot tape marking and Ink Jet printing are acceptable.

Marking on pipe shall include the following and shall be applied at intervals of not more than 1.5 meters:

a. Normal size (i.e. 32mm)
b. Standard PE designation (i.e. PE 80)
c. The Standard Dimension Ratio (i.e. SDR 9 or SDR 11)
d. Marking the product with the applicable standards designation (EN 12201).
e. Production date
f. Nominal pressure rating of pipe (i.e. PN10)
g. Manufacturer's Name
h. Country of production

IV-3-A-3-6-2-3 Service Identification Stripes

PE Pipes shall be permanently color-coded with stripes for instant identification as potable water service pipes. Stripes shall be provided by co-extruding four (or more) equally spaced blue color stripes into the pipe outside surface. The striping material shall be the same material as the pipe material except for color. ***Stripes printed on the pipe outside surface shall not be acceptable.***

For applications other than potable water, i.e. Irrigation and drainage, pipes are to be colored black.

IV-3-A-7 Manufacturer's Quality Control

The pipe manufacturer shall have an established quality control program responsible for inspecting incoming and outgoing materials. Incoming PE materials shall be inspected for density, melt flow rate, and contamination. The cell classification properties of the material shall be certified by the supplier, and verified by Manufacturer's Quality Control. Incoming materials shall be approved by Quality Control before processing into finished goods. Outgoing materials shall be checked for:

a. Outside diameter and wall thickness as per EN 12201-Part 2 at a frequency of at last once/hour or once/coil, whichever is less frequent.
b. Out of Roundness at a frequency of at least once/hour or once/coil whichever is less frequent.
c. Quality Control shall verify production checks and test for:
d. Melting Index as per ISO 1133 at a frequency of at least once per extrusion lot.
e. Hydrostatic Strength testing (up to Ø110mm) as per EN 921 at a frequency of at least once per day per line.
f. All fabricated fittings shall be inspected for joint quality and alignment.

IV-3-A-7-1 Permanent Records

The Manufacturer shall maintain permanent QC and QA records.

IV-3-A-7-2 Compliance Tests

Manufacturer's inspection and testing of the materials. In case of conflict with Manufacturer's certifications, the Contractor, Project Engineer, or Owner may request retesting be the Manufacturer or have retests performed by an outside testing service. All retesting shall be at the requester's expense, and shall be performed in accordance with the Specifications.

IV-3-A-8 Characteristics

IV-3-A-8-1 External Aspect of Pipes

Pipe surface shall be smooth, free from scoring, pinholes ,and other surface defects. Pipe ends must be cut clean and perpendicular to the axis of the pipe . End caps at pipe extremities are required in order to prevent unwanted matter entering the pipe during storage.

IV-3-A-8-2 Engineering Characteristics

The limitation on the outside diameter and ovality shall confirm to PR-EN 12202-2 as follows:

Ovality	OD Max	OD Min	OD
1.2	16.3	16.0	16
1.2	20.3	20.0	20
1.2	25.3	25.0	25
1.3	32.3	32.0	32
1.4	40.4	40.0	40
1.4	50.4	50.0	50
1.5	63.4	63.0	63
1.6	75.5	75.0	75
1.8	90.6	90.0	90
2.2	110.6	110.0	110

The pipes thickness shall depends to the properties used in manufacturing and shall conform to PR-EN 12202-2 and nominal pressures of PN10, PN12.5 and PN16bars for PE80 material and PN10, PN12.5, PN16 bars and PN20 for PE100 material.

STANDARD: PR-EN 12201 - 2/TC 155									
PE 80 MATERIAL									
	PN 10			**PN 12.5**			**PN 16**		
	SDR 13.6 S-6.3			**SDR 11 S-5**			**SDR 9 S-4**		
OD	e min.	e max.	ID (*)	e min.	e max.	ID (*)	e min.	e max.	ID (*)
Mm	Mm	mm	mm	mm	mm	mm	mm	mm	mm
16	-	-	-	-	-	-	2.0	2.3	11.7
20	-	-	-	2.0	2.3	15.7	2.3	2.7	15.0
25	2.0	2.3	20.7	2.3	2.7	20.0	3.0	3.4	18.6
32	2.4	2.8	26.8	3.0	3.4	25.6	3.6	4.1	24.3
40	3.0	3.5	33.5	3.7	4.2	32.1	4.5	5.1	30.4
50	3.7	4.2	42.1	4.6	5.2	40.2	5.6	6.3	38.1
63	4.7	5.3	53.0	5.8	6.5	50.7	7.1	8.0	47.9
75	5.5	6.2	63.3	6.8	7.6	60.6	8.4	9.4	57.2
90	6.6	7.4	76.0	8.2	9.2	72.6	10.1	11.3	68.6
110	8.1	9.1	92.8	10.0	11.1	88.9	12.3	13.7	84.0
125	9.2	10.3	105.5	11.4	12.7	100.9	14.0	15.6	95.4
140	10.3	11.5	118.2	12.7	14.1	113.2	15.7	17.4	106.9

STANDARD: PR-EN 12201 - 2/TC 155									
PE 80 MATERIAL									
160	11.8	13.1	135.1	14.6	16.2	129.2	17.9	19.8	122.3
180	13.3	14.8	151.9	16.4	18.2	145.4	20.1	22.3	137.6
200	14.7	16.3	169.0	18.2	20.2	161.6	22.4	24.8	152.8
225	16.6	18.4	190.0	20.5	22.7	181.8	25.1	27.8	172.1
250	18.4	20.4	211.2	22.7	25.1	202.2	27.9	30.8	191.3

OD = Outside Diameter
ID (*) = Average Inside Diameter
e = Wall Thickness
PN = Nominal Pressure Ratings in Bar

STANDARD: PR - EN 12201 - 2/TC 155												
PE 100 MATERIAL												
	PN 10			PN 12.5			PN 16			PN 20		
	SDR 17 S-8			SDR 13.5 S-6.3			SDR 11 S-5			SDR 9 S-4		
OD	e min.	e max.	ID (*)	e min.	e max.	ID (*)	e min.	e max.	ID(*)	e min.	e max.	ID (*)
mm	Mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
16										2.0	2.3	11.7
20							2.0	2.3	15.7	2.3	2.7	15.0
25				2.0	2.3	15.7	2.3	2.7	20.0	3.0	3.4	18.6
32	2.0	2.3	27.7	2.4	2.8	20.0	3.0	3.4	25.6	3.6	4.1	24.3
40	2.4	2.8	34.9	3.0	3.5	25.6	3.7	4.3	32.1	4.5	5.1	30.4
50	3.0	3.4	43.8	3.7	4.2	32.1	4.6	5.2	40.2	5.6	6.3	38.1
63	3.8	4.3	55.3	4.7	5.3	40.2	5.8	6.5	50.7	7.1	8.0	47.9
75	4.5	5.1	65.7	5.6	6.3	50.7	6.8	7.6	60.6	8.4	9.4	57.2
90	5.4	6.1	78.8	6.7	7.5	60.6	8.2	9.2	72.6	10.1	11.3	68.6
110	6.6	7.4	96.4	8.1	9.1	72.6	10.0	11.1	88.8	12.3	13.7	84.0
125	7.4	8.3	108.6	9.2	10.3	88.9	11.4	12.7	100.9	14.0	15.6	95.4
140	8.3	9.3	122.8	10.3	11.5	100.9	12.7	14.1	113.2	15.7	17.4	106.9
160	9.5	10.6	140.4	11.8	13.1	113.2	14.6	16.2	129.2	17.9	19.8	122.3
180	10.7	11.9	157.4	13.3	14.8	129.2	16.4	18.2	145.4	20.1	22.3	137.6
200	11.9	13.2	174.9	14.7	16.3	145.4	18.2	20.2	161.6	22.4	24.8	152.8
225	13.4	14.9	196.7	16.6	18.4	161.6	20.5	22.7	181.8	25.2	27.9	171.9
250	14.8	16.4	218.8	18.4	20.4	181.8	22.7	25.1	202.2	27.9	30.8	191.3

OD = Outside Diameter
ID (*) = Average Inside Diameter
e = Wall Thickness
PN = Nominal Pressure Ratings in Bar

IV-3-A-8-3 Mechanical Characteristics

All manufactured pipes shall pass the stress test conforming to the requirements of PR-EN 12202-2 using test method of EN 921/ISO 1167. Stress test shall be the deciding factor in accepting or refusing the pipe.

Produced pipes shall pass the internal pressure test (acceptance test) using test method per EN 921.

PE class	Reqts	Stress	Temp.
PE 100	>100hrs	12.4MPa	20 °C
PE 80	>100hrs	10.0MPa	20 °C

Note: The Contractor must give the Engineer a report specifying that the pipes he will install fits with the specifications described.

IV-3-A-8-4 Effect of temperature on working pressure of PE Pipe

Nominal pressure0 of PE pipes is the service pressure at 20°C with a service life of 50 years. For the use of Polyethylene pipes at higher temperature (up to a maximum of 60°C) the maximum working pressure according to the following table, should be reduced as shown on the following chart. These values are based on a pipe life time of 50 years.

Permissible Working Pressures For Pipes Transporting Water

Temperature in °C	Years of service	1	2	3	4	5	6
		Pressure rating					
		PN 2.5	PN 3.2	PN 1	PN 6	PN 10	PN 16
		Permissible working pressure					
10	1	3.4	4.3	5.4	8	13.4	21.4
	5	3.2	4.1	5.1	7.7	12.8	20.5
	10	3.2	4	5	7.6	12.6	20.2
	25	3.1	3.9	4.9	7.3	12.2	19.5
	50	3	3.8	4.8	7.2	12	19.2
20	1	2.9	3.8	4.8	6.8	11.4	18.2
	5	2.7	3.5	4.3	6.6	10.8	17.3
	10	2.7	3.4	4.2	6.4	10.8	17
	25	2.6	3.3	4.2	6.2	10.4	16.6
	50	2.5	3.2	4	6	10	16
30	1	2.5	3.1	3.9	5.9	9.8	15.7
	5	2.4	3	3.8	5.6	9.4	15
	10	2.3	2.9	3.7	5.5	9.2	14.7
	25	2	2.5	3.1	4.7	7.8	12.5
	50	1.7	2.2	2.7	4.1	6.8	10.9
40	1	2.1	2.7	3.4	5	8	13.4
	5	1.8	2.3	2.9	4.3	7.2	11.5
	10	1.8	2	2.5	3.7	6.2	9.9
	25	1.8	1.7	2.1	3.1	5.2	8.3
	50	1.2	1.5	1.8	2.8	4.6	7.4
	1	1.7	2.2	2.7	4.1	6.8	10.9
	5	1.2	1.5	1.9	2.9	4.8	7.7
50	10	1.1	1.3	1.7	2.5	4.2	6.7
	15	1	1.3	1.8	2.4	4	6.4
60	1	1.2	1.5	1.0	2.9	4.8	7.7
	5	-	1.1	1.4	2	3.4	5.4

Note: These working pressures do not apply for pipes exposed to UV radiation. The effect of such radiation can be eliminated or considerably reduced for up to ten years of service by the inclusion of suitable additives in the molding material.

IV-3-A-9 Pipe Connections

There are seven acceptable methods of joining polyethylene pipe with each other and with other pieces such as valves, flanges, etc.

1. Plastic Compression connection
2. Metal (ductile Iron) Compression connection
3. Electrofusion Fittings

4. Flange connection
5. Fabricated Fittings
6. Butt Fusion Welding
7. Special tapping fittings

IV-3-A-9-1 Plastic Compression Fittings for PE Pipes

This type uses mechanical anchoring that holds the pipe in place (clamp ring usually made of Acetalic resin or C-PVC)and a sealing gasket (EPDM or Rubber/food approved) to create a tight grip and prevent water from leaking. Pipes must be pushed inside the fitting without the necessity to disassemble the fittings. The following pipe OD to PN must apply:

- Pipes up to OD = 63mm with pressure rating maximum PN16
- Pipes OD = 75mm up to 110mm maximum PN10. For PN16 applications metal compression fittings or electrofusion fittings should be used.
- Pipes OD >110mm plastic compression fittings are not used. Metal compression fittings or electrofusion fittings should be used.

All fittings must pass the testing requirements of ISO 3458/3459/3501/3503. Manufacturers of compression fittings must show evidence of approvals from at least 2 internationally reputed institutes such as:

- DVGW Germany
- SVGW Switzerland.
- WRC United Kingdom
- KIWA The Netherland

IV-3-A-9-2 Metal (ductile iron) Compression Fittings for PE Pipes

When joining polyethylene pipe or for joining polyethylene pipe to another material with metal couplings, those couplings shall be fully pressure rated and fully thrust restrained such that when installed in accordance with manufacturer's recommendations, a longitudinal load applied to the mechanical coupling will cause the pipe to yield before the mechanical coupling disjoins. External joint restraints shall not be used in lieu of fully restrained mechanical couplings. Nominal pressure rating of fittings shall be 16 bar.

Materials used in the manufacturing of steel compression fittings shall conform to the following:

- Body : GGG 400 - DIN 1693 (epoxy coated, see below for detailed reqts)
- Lip Seal : EPDM
- Grip Ring : Ms 58 (dezincification resistant brass)
- Bolts : A2 (stainless Steel)

All steel compression fittings must be epoxy coated to the following characteristics:

- Minimum coating thickness 250 µm
- Approved for food handling to KTW standard
- Bacteriological approval to DVGW recommendation W270
- Regular quality tests to DIN 30 677 T2

IV-3-A-9-3 Electrofusion Fittings for PE Pipes

Electrofusion can be used for all polyethylene pipes irrespective of size and pressure rating as long as pipe and fitting are manufactured from polyethylene resin of the same class and series . It is possible to use fittings with higher pressure rating than pipe, but the opposite is strictly forbidden. Nominal pressure rating of fittings shall be 16 bar.

This type of fittings incorporates electrical heating coil that fuses pipe and fitting by sending an electrical current that heats up the polyethylene material of pipe and fitting at a specific voltage for a specified temperature and duration of time after which pipe and fitting fuse together and become integrated on the molecular level. Manufacturer recommendations for the electrofusion operation must be strictly followed.

Electrofusion machines used in the electrofusion process must be supplied by the same manufacturer of fittings. It strictly forbidden to fuse one manufacturer fitting with another manufacturer machine. Installers of Electrofusion fittings must strictly adhere to both fittings and equipment manufacturer's recommended procedures.

IV-3-A-9-4 Flange Connections

Flange connections shall be installed in accordance with the Manufacturer's recommended procedure. Flange faces shall be centered and aligned to each other before assembling and tightening bolts. In no case shall the flange bolts be used to draw the flanges into alignment. Bolt threads shall be lubricated, and flat washers shall be fitted under the flange nuts. Bolts shall be evenly tightened according to the tightening pattern and torque step recommendations of the Manufacturer at least 1 hour after initial assemble, flange connections shall be re-tightened following the tightening pattern and torque step recommendations of the Manufacturer. Nominal pressure rating of fittings shall be 16 bar.

1. Flanged Connections: Flanged connections shall consist of the following parts/fittings
   - Coupler (Electrofusion)
   - Flanged Adaptor
   - Backing Flange
   - Flange Seal

   1.1 The coupler for jointing plain-end polyethylene (PE) pipe to PE flanged items shall be of the electrofusion type that heats up the PE material of the pipe to the PE material of flanged fitting. Pressure rating of the coupler shall be no less than 16 bar and made of the same PE resin, class and series as the pipe.

   1.2 The flanged adaptors for jointing plain-end pipe to flanged items shall be of the socket fusion type and made of polyethylene (PE) material of the same class and series as the pipe. Pressure rating of the flanged adaptor shall be no less than 16 bar.

IV-3-A-9-5 Fabricated Fittings

Fabricated fittings shall be made by heat fusion joining specially machined shapes cut from pipe, polyethylene sheet stock, or molded fittings. Fabricated fittings shall be rated for internal pressure service equivalent to the full service pressure rating of the mating pipe. Directional fittings such as elbows, tees, crosses, etc., shall have a plain end inlet for butt fusion and flanged directional outlets. Part drawings shall be submitted for the approval of the Project Engineer.

IV-3-A-9-6 Butt Fusion Welding

For pipes with diameters larger than 75mm, joints between end of the pipes and fittings may be made by butt fusion, and joints between the main and saddle branch fittings shall be made using saddle fusion using only procedures that are recommended b the pipe and fitting Manufacturer. The Contractor shall ensure that persons making heat fusion joints have received training according to the Manufacture's recommended procedure. The Contractor shall maintain records of trained personnel, and shall certify that training was received not more than 12 months before commencing construction.

Heat Fusion Training Services - Upon request, the Manufacturer must provide training in the Manufacturer's recommended butt fusion and saddle fusion procedures to the Contractor's installation personnel, and to inspectors representing the Owner.

IV-3-A-9-7 Tapping Fittings

Branch connections to the main pipeline i.e. (the service lines) can be made using either tees or special tapping fittings (saddle fittings). These fittings can be either mechanical type, electrofusion type or metal type (ductile) and should be designed for the connection to polyethylene (PE) pipes

Tapping fittings according to DIN 3543 are provided for welding to PE-HD pipes. They are welded to the main pipe according to the indications of international standards.

Tapping fitting for main lines of PVC or PE-HD must have large contact surfaces and particularly for PE-HD special sealing elements in order to limit to a minimum the surface pressure.

When tapping the main pipeline, it is important to adhere to the respective guidelines for the pipe material. Only appropriate drills for the specific purpose, e.g. crown drills with sufficiently dimensioned flutes may be used. The construction of the drill must prevent the milled-out piece from falling into the pipe.

The material of the main pipeline determines the saddle width of the tapping fitting. The minimum width should be 100 mm for mechanically fastened fittings with rubber seals on PE-HD main lines.

Service lines must be designed to prevent transfer of additional of length to the connection points of the main pipe. Pipes passing through a wall must be lead through a protective pipe sleeve which, as far as drinking water pipelines are concerned, must be in accordance with the requirements of DIN 1988. Suitable water fittings are available for wall pipe sleeves for service lines.

IV-3-A-10 Installation Of Polyethylene Pipe System

IV-3-A-10-1 Foundation & Bedding

Pipe shall be laid on grade and on a stable foundation. Unstable or mucky trench bottom soils shall be removed, and a 150mm foundation or bedding of compacted Class I material shall be installed to pipe bottom grade. Excess groundwater shall be removed from the trench before laying the foundation or bedding and the pipe. A trench cut in rock or stony soil shall be excavated to 150mm below pipe bottom grade, and brought back to grade with compacted Class I bedding. All ledge rock, boulders and large stones shall be removed.

IV-3-A-10-2 Pipe Laying

1. In case of outdoor temperatures lower than 0°C, it is recommended to lay polyethylene pipes only under application of particular measures. Pipe ends and pipeline elements must be cleared prior to installation, damaged parts must be removed. Cuts are to be executed vertically to the pipe axle with the aid of suitable equipment, e.g. a fine-toothed saw. Cutting of the pipes can be made, too, using a casing cutter for plastic pipes. Burrs and uneven areas are smoothed down using suitable tools, e.g. a shaver or a scraper. The cut ends are then prepared for the jointing method to be used.
2. When lifting pipes with slings, only wide fabric choker slings shall be sued to lift, move, or lower pipe and fittings. Wire rope or chains shall not be used. Slings shall be of sufficient capacity for the load, and shall be inspected before use. Worn or defective equipment shall not be used.
3. Exercise care to keep foreign material and dirt from entering pipe during storage, handling, and placing in trench. Close ends of in-place pipe at the end of any work period to preclude the entry of animals and foreign material.
4. Do not lay pipe when trench bottom is muddy or frozen or has standing water.

5. Use only those tools specifically intended for cutting the size and material and type pipe involved. Make cut to prevent damage to pipe and to leave a smooth end at right angles to the axis of the pipe.
6. Unwinding of pipe coils can be carried out by various methods. Pipes with an outside diameter up to 63 mm can be unwound from the coil in a vertical position whilst securing the pipe end. For larger diameters it is recommended to use an unwinding mechanism. The coils can, for instance, be placed flat onto a rotating wooden or steel cross and be unwound manually or with the aid of a slow-moving vehicle.

The pipes must be unwound in a straight manner without any buckling. Spiral unwinding must be avoided.

When unwinding pipes from drums or coils it is essential to pay attention that the pipe end cannot spring outwards when loosing the fastening. As considerable forces are released, particularly from the large diameter pipes, take the necessary measures of precaution (danger of accident !). Drums should unwound from the top.

When unwinding the pipes, note that the flexibility of the polyethylene pipes is subject to the ambient temperature. At temperatures near the freezing point, pipes exceeding 75 mm of outside diameter are to be warmed, if possible. This can be carried out by pumping warm water through the coil or by using non-pressurized steam or hot air (max. 100° C).

Temperature changes cause alterations of length. This must be taken into consideration when cutting and installing the pipeline. 1 m of polyethylene pipe will elongate by 0.2 mm per °C in case of an increase in temperature and will shorten by 0.2 mm per °C in case of a decrease in temperature.

Temperature of Pipe laying	Smallest Admissible Bending Radius
20° C	20 x d
10° C	35 x d
0° C	50 x d

Note: Directional changes of the pipeline profile are achieved by installing pipe bends. To a limited degree the elasticity of the pipe material can be used to bend the pipe even without pre-warming. The smallest admissible bending radius must, however, not fall below the values given in the table above.

IV-3-A-10-3 Backfilling

Pipe embedment backfill shall be Class I or II material placed and compacted to at least 90% Standard Proctor Density in 150mm lifts to at least 150mm above the pipe crown.

IV-3-A-10-4 Final Backfilling

Final backfill shall be placed and compacted to finished grade. Native soils without debris, stones, boulders, clumps, frozen clods or the like larger than 200mm in their largest dimension may be used.

Note: Consulting the Manufacturer during installation phases is recommended to obtain detailed information on the methods and techniques used for proper execution.

IV-3-A-11 System Pressure Testing

During pressure tests on polyethylene pipes, the properties of the material cause elongation of the pipes to take place. The test results can be further influenced by changes in the temperature of the pipe wall while the test is in progress. This is due to the relatively high coefficient of thermal expansion of polyethylene pipes. The temperature rise in the pipe wall causes a drop in pressure. For guidance purposes it can be assumed that a temperature change of 10 K results in a pressure change of ~ 0.5 to 1 bar. When carrying out the pressure test, it is, therefore, desirable to keep the temperature of the

pipe wall as constant as possible to ensure that the temperatures at the start and finish of the pressure test are at the same level. For this reason, particular importance attaches to the temperature measurement.

It is also important to ensure that each pipeline is carefully vented, since air trapped in the line can influence the variation of the pressure drop with time. Due to an effect similar to that of a compressed-air chamber, the rate of pressure drop diminishes, which in turn could conceal an increase in the rate possibly caused by a leak. Any air still in the line - at joints and fittings - should be dissolved in water during the preliminary test. A pressure drop also results from temperature fluctuations and expansion of the polyethylene pipes.

In order that the often appreciable temperature influences can be largely eliminated, the tests should where possible be carried out at times of day when temperature fluctuations are small. The temperature level should be approximately the same at the start and finish of the test. Preliminary tests are essential in order that the material related elongation of the line can take place. The increase in the volume of a line at a testing temperature of 20°C and at nominal pressure amounts in the case of polyethylene pipes to 1.5 - 2%. This elongation takes place over a period of time, but is almost completed after 12 hours. At a testing pressure of 1.3 x PN, elongation increases by about 0.5%.

A pressure drop must thus be expected during the main pressure test, without any leakage having occurred at any point in the line.

This behavior is shown in the following diagram in the case of a PE-HD pipe, the test pressure of which has been intermittently adjusted (every 2 hours).

With the air vents open, it is expedient to fill the line slowly from its deep point, so that the air can escape. As regards the filling of the line, the following empirical values can be recommended:

DN	Inflow in I / s
50	0.1
65	0.1
80	0.2
100	0.3
125	0.5
150	0.7
200	1.5
300	3

IV-3-A-11-1 Execution of Test

The correct pre-conditioning of the pipeline is absolutely vital for the acceptance of the main test. This preliminary conditioning serves to bring the pressure time and temperature dependent changes in volume to a steady state, thus ensuring that the results obtained during the main test are reliable.

The preliminary conditioning must be carried out using one and a half times nominal pressure, to be checked and corrected if necessary at two hourly intervals. Duration of the preliminary test is 4 hours for pipelines without joints and 12 hours for pipelines with joints.

During the main test, it must be taken into consideration that the polyethylene pipeline material may not have completed the expansion process; Therefore, the main test shall be started no sooner than 2 hours after the last pressure increase in the preliminary tests.

Test pressure during the main test is at 1.3 of the nominal pressure.

The following test periods apply:

DN	Test Duration in Hours
< or = 150	3
200 - 400	6

For the main test, the results are deemed to be satisfactory when the pressure loss observed from the pressure of the polyethylene pipeline is < or = 0.1 bar per hour over the test period.

The so-called "short test" may be used for pipelines up to approx. 30m and nominal diameter not more than DN 50.

The test pressure for the short test is 1.5 times the nominal pressure. The test pressure is applied to the pipe and the first reading taken after 30 minutes. Note that this pressure is usually slightly less than initial pressure due to the normal expansion of the pipeline under pressure, but no additional "top-up" pressure should be applied.

For the short test the results are deemed to be satisfactory when pressure loss from the PE-HD pressure pipeline is < or = 0.1 bar per 5 min.

IV-3-A-12 Test of Disinfection of Pipes and Reservoirs.

Provide equipment, gauges,temporary connections, chlorine and water needed for flushing and disinfection after all work has been completed.

Before commencing disinfection, flush main until effluent is clean and then clean as directed. 1 to 2 times volume of pipe is usually required for such flushing.

After closing all pipeline's exit, the Contractor shall fill pipelines with clean water mixed with chlorine dose of 20 mg per liter. Wait for 24 hours, then measure residual chlorine by taking a sample to the lab and perform a bacteriological test in the presence of the Engineer. If any harmful signs have appear, disinfection process must be redone and another test must be taken until the test gives a results acceptable to the Engineer.

After the completion of the work, the Contractor must fill the reservoirs with clear water and wait for at least 72 hours and check if the water level stays as it was. If not, the Contractor has to fix the reservoirs on his own expense.

IV-3-B STEEL PIPES AND FITTINGS

IV-3-B-1 Quality Requirements

Steel pipes for use in the Works shall be made by an approved manufacturer. and shall meet the requirements of B.S. 534, 1387, 3600 and 3601 or American Water Works Association Standard C202, or equivalent European standards, carbon content shall not exceed 25 percent. Unless specified otherwise all steel pipes shall have minimum pipe wall thickness schedule 40 for nominal pressures up to PN 40, for higher pressures NP 64 and more wall thickness should comply schedule 80.

Pipe ends shall generally be plain squared for jointing with Viking-Johnson type couplings, or beveled for butt welding joints or flanged with flanges according to B.S. 4504 for flanged joints or with a bell on one end for fillet welded lap joints.

Unless otherwise specified or directed by the Engineer, fittings, bends, branches, specials etc. for use with steel pipes shall be prefabricated, factory arcade and shall be equal in quality and strength to steel pipes. Ends of fittings etc. shall be plain squared, beveled or flanged to fit pipe ends.

Steel pipes and specials intended for laying below ground shall be cement mortar lined or epoxy lined internally, and epoxy or bitumen coated externally riot less than 150 micron thick. The hot bitumen of the coating shall be wrapped with bitumen saturated asbestos felt or glass-fiber mat and whitewashed. Other types of railings or coatings which may be required shall be as detailed in the Particular Specification. The ends of pipes shall be left uncoated for jointing. Sufficient lining, coating. and wrapping materials and implements thereto shall be provided to complete coating on uncoated sections after jointing and to make good after laying of pipes.

Steel pipes and specials to be laid above ground in open air shall be epoxy or cement mortar on the inside and painted on the outside not less than 150 micron thick.

Steel pipes and specials to be laid inside buildings shall be epoxy coated internally and externally 150 microns minimum thickness.

Mechanical joints for use with steel pipes shall be of tile Viking-Johnson sleeve type made by all approved manufacturer. The joints shall be watertight assembled and shall be sufficiently flexible to permit small deflections without impairing their watertightness Rubber rings to be used with joints shall comply with the requirements B.S 2494. Contractor shall supply sufficient quantities of specially sized pipes for cutting of closure pieces and of Johnson Couplings without center register to permit the insertion of closing sections in the pipelines.

Galvanized and black iron pipes and fittings shall comply with B.S, 1387 (Steel Tubes and Tubular Suitable for Screwing to B.S. 21 pipe threads). Fittings not included in B.S. 1387 shall comply with B.S. 143 (Malleable Pipe Fittings) heavy quality. Pipes and fittings ordered galvanized shall comply with the requirements of the applicable Clauses of the above mentioned British Standards.

The Contractor shall submit to the Engineer certificates from approved laboratories certifying that the pipes and fillings supplied comply with the requirements of the relevant specifications.

IV-3-B-2 Hauling and Handling of Pipes and Fittings

Pipes and fittings shall not be allowed to drop, roll freely or strike objects which may damage them. when fitting pipes or fittings by their open ends, special hooks or plates shaped to fit the wall shall be used. Chaining will be allowed on bare pipes only, wrapped pipes shall be lifted by padded straps at least 20 centimeters wide. Care shall be exercised in transporting, handful or storing pipes and fittings in order to avoid distortion, flattening, denting, scoring or any, other damage to pipes and fittings and to their outer coating and/or inner lining.

IV-3-B-3 Stringing of Pipes

Pipes of the various diameters and wall thickness shall be strung along the alignment as closely. as possible to their trial position.

Pipes and fittings strung alone the alignment shall be protected against intrusion of earth, mud. dirt and other foreign bodies, and against damage to tile outer coating. Pipes shall not be strung on the side of the trench where excavation material has been or is to be placed. Where necessary or as directed by the Engineer gaps shall be left in stringing in order to allow movement of vehicles or men across the alignment. Wrapped pipes shall be whitewashed unless they have been supplied with whitewash and the latter is in good condition after stringing.

IV-3-B-4 Handling of Mortar-Lined Steel Pipes

No internal hooks or similar equipment likely to damage the mortar lining shall be used. Excessive bending of the pipe that may cause cracking of the mortar lining shall be prevented.

IV-3-B-5 Repairs of Defective Pipes

Should laminations, cracks or other defects be discovered on ally pipe or its coating or its lining, the Engineer will issue instructions as to whether such defects shall be repaired or the defective part cut out or the defective pipe removed. Where the pipes were supplied by the Employer, he will pay the Contractor the cost of the repairs or other extra work necessitated thereby, but otherwise pipes shall be repaired or replaced by the Contractor at his own cost.

IV-3-B-6 Welding of Pipes

1. Welding Methods – All welds shall be made by the manual shielded metal-arc method. The welding procedure to be applied by the Contractor shall be submitted to the Engineer for approval, before the commencement of the work. All welding works shall be carried out by welders having passed the welders qualification tests in accordance with B.S. 4871 part 1 and

B.S. 4872 part 1, whichever is applicable. Welds will be either butt welds for plain-ended pipe joints or fillet welds for lap joints (bell and spigot). The use of welding machines with two outlets not be permitted; every welder shall work with a separate machine.

2. Electrodes – Electrode used for welding shall meet tile requirements of B.S. 639 and B.S. 4215. Generally with D.C. generators, Class E-100 (DCRP) electrodes shall be used. In any case, the electrodes proposed by the Contractor shall be subject to the Engineer's approval prior to their use.

   Electrodes shall be stored in the unopened original containers in such a manner as to prevent absorption or loss of moisture or mechanical damage to the coating. Electrodes in open containers shall be protected against moisture. Electrodes that have been damaged, moistened or otherwise deteriorated, shall be rejected.

3. Cleaning of Pipes – Pipe ends to be welded together shall be thoroughly cleaned of any dirt, oil, residues of paint and asphalt, and any other foreign matter that may adversely affect the quality of the weld. Paint and oil residues shall be removed with Kerosene or gasoline.

4. Welding of Joints – The number of beads in each weld seam shall be not less than two, and their thickness shall not exceed 3.0 mm.

   In butt welds, the thickness and number of the beads shall be so adjusted that the height of the weld reinforcement shall be not less than 0.8 mm and not more than 1.5 mm above the pipe surface. The width of the cover bead shall be approximately 3.0 mm more than the width of the groove before welding. In fillet welds the thickness of the throat shall be at least $0.5\sqrt{2}$ (= 0.707) of the pipe wall thickness. Cutting back of the edge of the bell shall be kept to a minimum. All weld metal shall be thoroughly fused to the parent metal and to the previously placed weld metal.

   After the completion of each bend, the weld shall be thoroughly cleaned of all scale, slag, or dirt. All spots on the weld where electrodes are changed shall also be cleaned. A peering hammer and steel brush may be used for cleaning, provided it is done to sound and bright metal. The finished seam shall be thoroughly cleaned by means of steel brushes.

5. Fitting-up of Pipes – In butt joints the root opening between the pipes shall be such as will ensure full penetration without burn-through in accordance with the approved welding procedure. When aligning pipes, the offset between pipe ends about to be joined shall be reduced to a minimum. External line-up clamps shall be used to center pipes. Internal clamps may be used when approved by the Engineer.

   The external line-up clamp may be removed only after 50% of the root bead has already been welded, in segments equally distributed around the pipe, not shorter than 7 cm each; their quality, and thickness shall not be inferior to those required for root welding. The internal clamp may be removed only after the whole of the root bead has been welded.

   In lap joints the plain end of one pipe shall be shoved in until it abuts against the shoulder of the bell, so that the gap between the mortar lining of the two pipes is reduced to a minimum

6. Welding Positions – The welds shall be made either by roll welding or position welding. Roll welding will be permitted, provided alignment is maintained by the use of skids and roller dollies supporting two or more lengths of pipe. Position welding shall be done with the pipes resting on skids at the proper height over or alongside the trench, so as to permit the completion of, the weld on the whole circumference. All requirements as to the quality of the welds shall apply equally to roll welding and position welding.

7. Jointing of Line Sections – Pipes shall be connected to each other by welding as specified above, they are placed on suitable supports on the trench bottom or on the ground beside the trench.

   The length of sections to be welded together before lowering them into the trench shall be as directed by the Engineer. The position of every pipe or elbow in the section shall be such that, when the section has been lowered to the trench bottom the longitudinal seams will be located

between the figures 10 and 2 on the clock face, so that repairs on the seams can be done in the trench without necessitating deep excavation.

Before being connected to the line, the inside of each pipe and each elbow shall be cleaned.

8. Welding Mortar-lined Pipes – When butt-welding mortar-lined pipes, the Contractor shall take steps to ensure the continuity of the lining at the joints. The materials and methods employed to this end shall be as recommended by the manufacturers of the pipes, and approved by the Engineer or as directed by the Engineer. The cost of all materials and work required to ensure the continuity of the cement mortar lining shall be deemed to be included in the unit rates for supply laying and joining of the pipes and shall not be paid for separately,.

   In pipes with lap joints which are not accessible from the inside, a sufficient quantity of mortar shall be placed in the bell just before the new pipe is shoved in. After the new pipe is laid in place, excessive mortar shall be removed and the inside of the joint finished by pulling a rubber ball or equivalent through the joint. Where the inside of the pipe is accessible, the mortar lining at the joint shall be completed by plastering on with a good bond to the existing lining and toweling smooth and flush with the adjacent mortar lining. The mortar employed as specified above shall conform in all respects to requirements of Subsection 217.4.9 of this Specification.

9. Repair of Weld Defects – The Engineer may permit repairs of defects in the root or filler beads to be made, but any weld that shows evidence of repair work having been done without such permission may be rejected. Pinholes and undercuts in the final bead may be repaired but such repairs shall be subject to the Engineer's approval. Undercuts not exceeding 1.0 mm in depth will not be considered as defects.

   Before repairs are made, the defective areas shall be removed by chipping, grinding, or flame gouging. Any slag and scale shall be removed by wire brushing. When cracks are found, the entire seam shall be cut away and re-welded.

   The Contractor shall clearly mark with oil paint oil top of tile pipe any defect that has been discovered in the pipe or weld.

IV-3-B-7 Miscellaneous Welding Works

1. Cutting and Preparing Pipes for Welding – The plane of square cuts shall be perpendicular to the pipe axis. Oblique cuts shall be accurately made to the required angle and in such a manner that the cut edge is in one plane. Pipe ends for butt welding shall be beveled to an angle of 30 with the plane of the edge, with a permissible deviation of 0° to +50°. All cutting. shall be done by mechanical tools, or by acetylene flame-cutting by means of a special cutting device or by Arc-air (carbon electrode with air jet). Flame cut surfaces shall be perfectly clean, and where necessary, the cut surfaces shall be filed smooth. Mortar-lined pipes shall always be cut by Arc-air cutting equipment. After the metal has been cut through to the mortar lining, the latter shall be carefully broken along the cut and the pipe edge prepared for welding as required above.

2. Welding of Flange – The welding of flanges to pipes shall be of the same quality as that specified for pipe fields. Slip-on flanges shall receive all interior weld inside the flange opening, in addition to the external weld. Weld-neck ranges shall be attached to pipe ends as specified above for the welding together of pipes, care being taken to ensure a perfect concentric alignment between pipe and flange.

   Flanges shall be welded to pipes very carefully, so that the faces of the flanges shall be truly perpendicular to the pipe axes. Flange faces shall be kept free from weld material or other defects such as splutter, dirt, etc. All defects in flange faces that may interfere with the proper sealing of flanges shall be repaired.

3. Fabricated Fittings – Where shown on the Drawings or where directed by the Engineer, fabricated fittings, specials. etc., as specified hereafter, will be used instead of factory-made fittings.

Welded elbows shall consist of suitable obliquely cut pieces of pipe ("mitres") welded together. The mitres shall be cut to the exact dimensions shown on the Drawings and accurately fitted together so that after welding the completed elbow will have the exact shape and dimensions shown on the Drawings. The ends of mitres shall be beveled for welding as specified above. In all elbows of 12" (300 mm) diameter and larger the seams between mitres shall also receive an internal weld pass which shall be made after the weld root has been thoroughly cleaned.

Fabricated T and Y branch connections shall be produced by cutting the branch pipe to the correct intersection fitting the curvature of the main pipe, cutting the required opening in the main pipe and welding the branch to the main pipe. Where shown on the Drawings or instructed by the Engineer the fabricated T and Y branches shall be reinforced by welded saddles. The saddle shall be cut and bent to the required shape and slipped over the branch, its outside edges shall be welded to the main pipe while the edge of its opening shall be welded to the branch pipe.

IV-3-C ACCESSORIES

The Ductile iron pipes or pieces, joints, connections, parts and accessories involved in the project shall comply to the following Standards, Norms and Specifications:

Pipes:	NF A 48-801, NF A 48-806, NF A 48-841, ISO 2531, BS EN 545-1998.
Connections and joints:	NF A 48-863, NF A 48-842, NF A 48-830, NF A 48-860, NF A 48-870, BS EN 545-1998, ISO 2531.
Joint's fittings:	NF T 47-305, ISO 4633
External Protection (Zinc coating):	NF A 48-852, ISO 8179
External Protection (Bituminous coating):	EN 545-1998, ISO 2531.
Internal Protection (Cement mortar):	NF A 48-901, NF A 48-806, ISO 4179, EN 545, BS EN 545-1998.
Excellency of Productions and Installations:	ISO 9001
Testing:	ISO 2531
Special Protection (Polyethylene):	ISO 8180

IV-3-C-1 Valves

IV-3-C-1-1 General

The valve, components and all its related parts and accessories shall comply to one of the International Standards Institutes requirements (i.e. ISO, BSS, DIN, etc…).

Manufacture(s) must have the Label of Quality ISO 9001 to be qualified as supplier. The contractor shall not submit any materials for approval if not compatible with required specifications and from an approved manufacture.

IV-3-C-1-2 Ductile Iron Gate valves

The vales shall be made of ductile iron, of resilient seated type and non-rising stem and straight passage, for diameters > 1.5" inches and sustain (Pmax.allow.) :25 bars, for (Pmax.allow.) > 25 bars, use cast steel valves.

The valves and components must pass the hydrostatic pressure test at the manufacture and sustain the maximum allowable pressure to NFE 29-311, ISO 5208 for different PN selects, and must be approved and certified by known Quality Control Offices i.e. BUREAU VERITUS or other.

IV-3-C-3-1-2-1 Ductile Iron Gate Valves PN16

The ductile iron valves and components shall comply to:

- Ductile iron valves to ISO 7259 Type A, BS 5163 Type A, NF 29-324, DIN 3352 Section 4A/B.
- Use only valve furnished with seal bush replaceable under pressure and comply to NFE 29-310, NFE 29-311.
- The spacing between the two flange of the valve complies to ISO 5752, the drilled holes in the flanges to ISO 7005-1/2, ISO 2531.
- Body and bonnet is made of ductile iron to GS 400-15 with powder epoxy coating, minimum 150 microns to ISO 8501 grade SA 2.5
- Nut and yoke to SG 400-15 ductile iron, coated with ethyl vynil acetate.
- Bolts and nuts shall be of galvanized steel with rubber washers reinforced with steel rings.
- Gate to GS400-15 ductile iron, fully covered with EPDM rubber.
- Stem 13 % chromium stainless steel.
- Seal bush is made of bronze.
- Bonnet and bush seals, 70 Shore A Nitrite Rubber.
- Hydrostatic Pressure Test: Passed 24 bars for body, 18 bars for components.

IV-3-C-3-1-2-2 Ductile Iron Gate Valves PN25

The ductile iron valves and components shall comply to:

- Valves shall comply to ISO 7259 Type A, BS 5163 Type A, NF 29-324, DIN 3352 Section 4A/B.
- Use only valve furnished with seal bush replaceable under pressure and comply to NFE 29-310, NFE 29-311.
- The spacing between the two flange of the valve complies to ISO 5752, the drilled holes in the flanges to ISO 7005-1/2, ISO 2531.
- Body and bonnet is made of ductile iron to GS 400-15 with powder epoxy coating, minimum 150 microns to ISO 8501 grade SA 2.5
- Nut and yoke to SG 400-15 ductile iron, coated with ethyl vinyl acetate.
- Bolts and nuts shall be of galvanized steel with rubber washers reinforced with steel rings.
- Gate to GS400-15 ductile iron, fully covered with EPDM rubber.
- Stem 13 % chromium stainless steel.
- Seal bush is made of bronze.
- Bonnet and bush seals, 70 Shore A Nitrite rubber.
- Hydrostatic Pressure Test: Passed 37.50 bars for body, 27.50 for components.

IV-3-C-1-3 Butterfly Valves

Butterfly valves shall conform to BS 5155 and used where expressly mentioned.

Butterfly valves shall have a high grade cast iron body to BS 1452 designed to the specified working and test pressures. The pressure rating of the valve shall be cast in the valve body.

The disc shall be of high grade cast iron to BS 1452 or nodular cast iron to BS 2789 to the defined working and test pressures. It shall has a convex shape designed to achieve low head loss characteristics. The valve shafts shall be of stainless steel operating in self lubricating bushes in the body.

The valve seat shall be of gunmetal to BS 1400. The sealing ring shall be a renewable Ethylene Propylene Diene Monomer (EPDM) rubber attached to the disc edge by a sectional bronze retaining ring to form a resilient and durable seal.

The valves shall be fitted with handwheel actuators not exceeding 500 mm diameter incorporating gearing to allow opening and closing by manual operation at the pressure stated using an effort no greater than 26 kg on the handwheel supplied.

In all cases, the gearing shall be designed to close the valve, from fully open to fully closed in a period of not less than ten minutes with this effort. Actuators shall be designed so as to close the valves when the handwheel is turned in a clockwise direction; the direction of closing shall be clearly cast on the handwheel. Position indicators shall be fitted to all actuators.

Where required, valves shall be electrically actuated with a manual override. Remote actuation shall be provided with a visual indication of valve open, valve closed and percentage opening together with fault indication.

A performance curve, relating percentage valve travel, open area and discharge coefficient shall be submitted to the Engineer. The head loss coefficient with valve fully open shall be defined.

All valves shall be tested in accordance with BS 5155 and pressure and material test certificates shall be submitted to the Engineer for approval.

IV-3-C-1-4 Ball Float Valves

Ball float valves which are to be installed within reservoirs shall be of the delayed action type to eliminate inflow at small valve openings. They shall be fitted with a stilling chamber, auxiliary float valve and inlet bellmouth with regulating valve. The main valve shall be fitted with long actuating lever to provide a long float travel for slow valve closure.

Valves shall be of the right angle pattern type with flanged inlet and have a resilient synthetic rubber disc which forms a drop tight seal against a removable seat insert. Valves shall be free of vibration under the specified working conditions. Flanged tapers shall be provides on the inlets as necessary to suit the size of valves proposed.

Valves shall be capable of withstanding the maximum static pressure and of passing the maximum flow rate. Orifice plates shall be provided as necessary to absorb excess working pressure at the initial flow rates indicated.

The pressure rating of the valve shall be cast into the body of the valve.

IV-3-C-1-5 Cast Steel Valves

The cast steel valves shall be used where ductile iron valves are not permissible to operate at pressure > 25 bars, and shall comply to NF E 29-328, NF E29-331.

IV-3-C-2 Valves Accessories

1. Steel operating hand wheels: BS 5163 for cast iron, and BS 1452 for grade 10. Hand wheels are to be marked “CLOSE” with an arrow to indicate clockwise direction for closure.
2. Valve caps: BS 5163, of cast iron BS 1452 grade 12 or malleable iron to BS 310. The set screw of valve cap is to be mild steel M12.

3. Operation keys: Combination prizing bar and lifting key tube, with 1.5 m vertical bar and 0.5 m horizontal bar.
4. Extension spindles for gate valves: steel to BS 2470 – M12, hot dip galvanized to BS 1387, size 18x18 mm for valves up to 200 mm and 24x24 mm for valves250 mm to 400 mm diameter. Length for each valve is to suit valve depth. Spindles are to have cast iron cap and coupling, BS 1452 grade 12 or BS 310 respectively, on both sides of the extension spindle (The cap for the operating spindle and coupling for connecting to vale). The set screws of caps and couplings are to be mild steel M12.
5. Protection tubes: Either UPVC, cast iron, or pre cast concrete. Shape, sizes and other constructional details are to be manufacture's standards and/or as shown on the drawings.
6. Surface boxes: BS 1426, frame and cover are to be cast iron to BS 1452 Grade 10, studs, bolts nuts and hinge pins are to be mild steel M12, chains are to be mild steel or made of wrought iron and lid is to have "W" cast on.
7. Lifting keys: are to be made of malleable iron.

IV-3-C-3 Air Valves (Ventouses)

Air valves, body and components shall comply to SG 400-15 ductile iron, and are to be installed as specified on the drawings, where needed and as directed by the Engineer.

Air valves are introduced into the water main in order to eliminate air collections at high spots and changes in slopes.

a. Single air valves are meant to discharge the trapped air automatically under normal operating conditions, (when pipes are under pressure).

b. Double air valves are mainly used to permit bulk air vent under pressure, blowing off air when filling the pipes with water, and air ingress during emptying. They are also used at steep slopes to protect against sharp pressure drop in case of accidental breakage.

Air valves shall be supplied with an isolating valve which permits the complete removal of the air valve from the main without affecting the flow of water.

Air valve are mounted on a vertical branch connection with at the top of the main.

Air valves shall operate automatically and shall be constructed in a manner that the operating mechanism will not jam in either position (open or close).

IV-3-C-4 Flowmeters

Generally, the different types of flowmeters used depend on the size selected. They are either, mechanical for diameters up to 300 mm, or electromagnetic for diameters greater than 300 mm.

All types of flowmeters should be suitable to allow the attachment of existing industry-standard electronic loggers without modification to the meters.

Mechanical flow meters shall be volumetric, jet or in-line helical vane (Woltmann) type to Standards ISO40641/BS 5728 EEC Specification with integral strainer . Meters shall be designed for minimum maintenance and shall incorporate best quality rotor bearings to ensure long working life.

Meter bodies shall be cast in spheroidal graphite iron to BS 2789. All internal parts shall be manufactured from non-corrodible materials.

Meters are for the measurement of potable water flow with a normal working temperature up to 30°C and a maximum working pressure of 16 bar. Meters shall be generally in accordance with the following table.

Meter Size (mm)	Qmax: PEAK Instantaneous Flow (minutes only) (m3/h)	Qn: MAXIMUM Continuous Flow at ± 2% measuring error (m3/h)	Qmin: MINIMUM Flow at ± 5% measuring error (m3/h)
15	3.0	1.5	0.036
20	5.0	2.5	0.050
25	7.0	3.5	0.082
32	10.0	4.5	0.127
40	20.0	6.5	0.182
50	80	40	0.55
80	200	120	0.70
100	250	180	1.20
150	600	400	3.00
200	700	550	5.00
250	1200	750	10.00
300	1500	1000	12.00

Measurement mechanisms shall be removable without the necessity of dismantling the meter from the main. Meters shall be equipped with a register indicating flow in metric units using a sweep hand and six figure counter and with dummy cover plates to seal the meter when removing the mechanism.

IV-3-C-5 Manholes

The construction of manholes and valve chambers shall be located as specified on the drawings and as directed by the Engineer during constructions:

- Excavation and backfilling generally shall comply with appropriate requirements of PART II, SECTION 1.
- Concrete works generally shall comply with the appropriate requirements of PART II SECTION 4.
- Ductile iron cover shall comply to ISO 1083, EN 124, or equivalent.
- Cement to be sulfate resisting to BS 4027 for sewage system and ordinary portland cement for drainage and other structures.
- Coating: Pitch epoxide coating for internal surfaces of concrete sewage manholes and chambers.
- Coating: Protective bituminous coating for external surfaces of concrete manholes, valve chambers, or other equal approved.

Manholes are to be precast or cast in situ as shown on the drawings and shall be completely water-tight. Particular attention shall be given to the joints between the pipes and the walls to ensure proper tightness against any leaks into the manholes.

Where valves are directed to be fixed in a chamber, etc. the necessary frames shall be placed in position using approved expanding shell bolts or an approved proprietary resin anchor system.

For precast units the Contractor shall obtain the Engineer's approval to all details of the precast units and method statement before commencing casting units.

All manhole covers located in roads shall be brought to the final finishing level of the pavements. The covers and frames shall have accurate seating faces to prevent rocking and the ingress of sand or water, and shall be fitted tight to resist overflow conditions or any leakage from under the frame base.

IV-3-C-6 Flanged Anchoring Pipe With Puddle Flange

Flanged anchoring pipes with puddle flange shall be used in the concrete walls of manholes, pressure breaker basin, discharge basin and water tanks as specified in the drawings or as instructed by the Engineer. The puddles flange will provide additional fixation to the pipe in the wall in addition to reduce or eliminate the water leakage.

The flanged anchoring pipe with puddle flange is made of ductile iron and shall comply to the appropriate requirements.

The installation requirements and fixation in concrete shall follow the manufacturing recommendations.

IV-3-C-7 Dismantling Joints

Self restrained dismantling joints, made from ductile iron, are used to ensure extensible connections between sections of pipe work, to be mounted next to valves to enable easy dismantling from pipe work or to permit jointing pipe work when butterfly valves is removed for maintenance.

The dismantling piece is to be flanged type composed of two parts, one sliding into the other, and a free flange to compress a trapezoidal section seal to ensure water tightness.

All steel with flanges are class PN 10 or PN 16 depending upon coupling location on the pipeline.

IV-3-C-8 Straightener

The required type of the flow straighteners shall be selected to stop the turbulence in the water pipes, and standard flanges to ISO PN 10.

IV-3-C-9 Ductile/Cast Iron Grating

The cover and frame shall be manufactured to ISO 1083, EN 124, or equivalent. Use rectangular grate and frames as specified on the plans and according to the following classification: Class D400; heavy duty; for minimum test load 40 tons.

The contractor shall submit certifications of Test Load according to British Standard Institute or equivalent and Quality Assurance according to the European Standard EN 124 section 10 or equivalent.

The grate shall bear the following information:

- The name of the manufacture, initials and identification mark,
- Initial and number relevant standards, example EN 124,
- Production excellency stamped by one of the known agencies Example: The French standard Institute (AFNOR) or the British Standard Institute (BSI),
- Initial of material used, example: GS for Ductile Iron,
- Load capacity. example: D400 for minimum test load 40 tons.

IV-3-C-10 Ductile Iron Frame and Cover

The cover and frame shall be made of ductile iron manufactured to ISO 1083, EN 124, or equivalent. Use only round covers and frames, minimum 600 mms for cover and 850 mms for frame, as specified on the plans and their use according to the following classifications:

Class E 600: Super heavy duty; used for industrial plants, ports, airports, etc…Minimum test load 60 tons.

Class D400: Heavy duty; for streets, roads. Minimum test load 40 tons.

Class C250: Medium duty; for sidewalks, gullies, parking areas accessible for lorries. Minimum test load 25 tons.

Class B125: Light duty; for sidewalks, parking areas only accessible to passenger cars.

The contractor shall submit certifications of Test Load according to British Standard Institute or equivalent and Quality Assurance according to the European Standard EN 124 section 10 or equivalent.

The cover shall bear the following information:

- The name of the manufacture, initials and identification mark,
- Initial and number relevant standards, example EN 124,
- Production excellency stamped by one of the known agencies Example: The French standard Institute (AFNOR) or the British Standard Institute (BSI),
- Initial of material used, example: GS for Ductile Iron,
- Nominal diameter and class designations,
- Load capacity. example: D400 for minimum test load 40 tons.

IV-3-C-11 Galvanized Steel Steps or Ladder

Manholes and pressure breaker basin shall be furnished with 1 inch galvanized steel steps: to BS 729.

The steel steps can be installed during the construction of the concerned structures or after construction in case or precast units as specified in the drawings or as directed by the Engineer.

When drilling into the concrete walls for installing the steel steps, the hole shall be cleaned thoroughly and the space between the rod and the concrete shall be filled properly with non shrink cement mortar as specified by the manufacture and provide good finishing to the surface.

IV-3-C-12 Cold Water Meter

For flanged water meter over 50nim diameter, shall be Woltmann horizontal type extra dry, magnetic transmission with an hydro-dynamically balance helix type sensitive at low flow rates and resistant to high flow rates. The minimum reading must be minimum 0.05 liter with a head loss lower than 0.05 bars at nominal flow.

(Qn), an EEC approval is compulsory. The totalizer must be equipped by an index wiper to always be easily readable numbers and an adequate filter unit must be installed upstream the meter. The meter must be Class B in all positions with internal mechanism interchangeable on site by an already calibrated one. The calibration device of the meter should be accessible without removing the internal chamber of measurement.

The protected epoxy coating body must be in cast iron for maximal admissible pressure 20 bars and in steel for 50 bars for nominal diameter 100 mm and above and be able to function under 3 meters of water. The maximum working temperature is 30°C for cold water and 90°C for hot water.

The register must be with minimum of 8 rollers and be able to rotate 360°C on site for easy reading and must be protected with a solid cap made either of plastic or metal.

The Water Meter must be pre-equipped for remote reading system:

- The choice of the pulse value must be independent from the pre-equipment.
- The proposed compatible communication equipment must be able to be installed on site without breaking any metrological seal.
- The pre-equipment and the proposed communication equipment must be both insensitive to magnets of 2500 gauss.
- The pre-equipment should allow to upgrade the meter with a remote reading device absolutely reliable in the long term (the register and the remote indicator must always indicate the same amount of forward volume, hence backflow must not be computing as forward volume).

For screwed water meter under 40mm diameter, shall be Turbine Single jet liquid filled type (five digit totally immersed in a hermetically sealed casing and filled with a lubricating fluid) with mechanical-transmission and reflecting electronic testing disc, excellent sensitivity at tiny flow rate and the minimum reading must be 0.05 liter with head loss lower than 0.2 bars at nominal flow (Qn). The easily readable numbers is assured by the lubricating fluid even in a flooded pit holes or in water contains suspended solids and should have a conical filter inserted in the inlet.

The maximum working temperature. is 30°C for cold water and 90°C for hot water.

The meter must be Class C (BS 5728/1, ISO 4064., EEC 75/33, OIML N049) for horizontal position and class B in any other position, and must have an external adjusting screw tamperproof. The body must be brass for no corrosion with permanent pressure 16 bars and can accept as an option, a non-return valve inserted at the outlet.

PART IV – CIVIL WORKS

4. Concrete

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IV-4-A CONCRETE

IV-4-A-1 Description

Concrete shall consist of a mixture of Portland cement, water and aggregates without air-entraining or water-reducing admixture unless specified otherwise.

IV-4-A-1-1 Concrete Materials

IV-4-A-1-1-1 Cement

The cement to be used is type C-S 42.5 for all concrete structures according to the Lebanese norm. The heat of hydration of cement measured by the method of "Bouteille Isolante" defined by "Centre d'Etudes et de Recherches de l'Industrie des Liants Hydrauliques CERILH" shall not exceed 70 calories/gram of cement at 7 days.

Where approved by the Engineer the cement could be Portland type, originating from manufacturers approved by the Engineer, shipped and sealed, labeled bags only. Cement delivered in bulk shall not be used. The quality of the Portland cement shall be equivalent to AASHTO M 85, Type I, II, III or V. A sack of cement shall weigh 50 (fifty) kilograms.

IV-4-A-1-1-2 Mixing of Cements

Only one (1) type or brand of cement shall be used in any one structural member. Mixing of types or brands will not be permitted.

IV-4-A-1-1-3 Tests and Acceptance

Cement shall be tested for conformance with AASHTO M 85 or British Standard 12 and shall have a compressive strength of standard cement mortar samples at twenty-eight (28) days of not less than two hundred fifty (250) kilograms per square centimeter. All cement is subject to the Engineer's approval and shipments of cement shall be accompanied by a manufacturer's Certificate of Guarantee and/or laboratory test certificate. The Engineer reserves the right to order a retest of the cement at any time. Approval of a cement quality shall not relieve the Contractor of the responsibility to fabricate concrete of the specified strength. The Contractor shall bear all costs in connection with the Certificates of Guarantee and laboratory tests. When tests of factory or field tests subsequent to the original approval tests show that the cement does not comply with the specifications, the entire consignment from which the sample was taken will be rejected and the Contractor shall immediately remove the rejected material from the site and replace it with cement, which meets the required specifications.

IV-4-A-1-1-4 Storage

Storage capacity shall be sufficient to meet the requirements for 30 (thirty) working days unless in the opinion of the Engineer the supply from the manufacturer is so limited that more storage capacity is necessary. Cement shall be stored in moisture-proof storage sheds in such a manner that the oldest is used first. Neither stale, caked nor reclaimed or re-sacked cement shall be used. The Contractor shall not store cement in areas subject to flooding.

Cement remaining in bulk storage at the mill prior to shipment for more than six (6) months or cement stored in bags in local storage by the Contractor or a vendor for more than three (3) months after shipment from the mill, may be retested before use and will be rejected if it fails to meet any of the requirements of these specifications.

IV-4-A-1-2 Aggregates

IV-4-A-1-2-1 Fine Aggregates

Fine aggregate shall conform to AASHTO M6 and shall consist of natural sand or crushed rock having hard and durable particles or, if approved by the engineer, other inert materials having similar characteristics, 100% passing 9.5 mm sieve and 2% to 10% passing 0.15 mm sieve. It shall not

contain harmful materials such as iron pyrites, coal, mica, shale or similar laminated materials such as flat and elongated particles or any materials which may attack the reinforcement in such a form or in sufficient quantity as to adversely affect the strength, durability and texture of the concrete.

IV-4-A-1-2-2 Coarse Aggregate

Coarse aggregate shall conform to AASHTO M80 and shall consist of gravel, crushed gravel, or crushed stone free from coating of clay or other deleterious substances. It shall not contain harmful or any other materials in such a form or in sufficient quantity as to adversely affect the strength and durability of the concrete. If necessary, coarse aggregate shall be washed to remove deleterious substances or for consistency of concrete color

IV-4-A-1-2-3 Combined Aggregate

Combined aggregate is composed of a mixture of coarse aggregates and fine aggregates. They shall be used only in proportions with the prior approval of the engineer. In no case shall materials passing No. 200 (0.075 mm) sieve exceed 3% by weight of the combined aggregate.

IV-4-A-1-3 Water

All sources of water to be used with cement whether for mixing or curing of concrete, or compaction of backfill around the concrete structures, shall be approved by the Engineer. If at any time during construction, water from an approved source becomes unsatisfactory, the Contractor shall provide satisfactory water from other main sources.

Water shall be free from injurious quantities of oil, alkali, vegetable matter and salt as determined by the Engineer. The water shall be reasonably clear and shall contain not more than one quarter (0.25) percent solids by weight. Water shall comply with the requirements of AASHTO T26 and BS 3148. If the specific conductance is less than 1500 micro ohms per centimeter the total solids contents requirement may be waived.

IV-4-A-1-4 Admixture

Where directed by the Engineer, all the necessary additives shall be used (protection of concrete in contact with water from the evaporation of lime, waterproofing,…). In particular a retarding admixture set shall be used. The admixture proposed for use shall be approved by the Engineer before it is incorporated into the Work. The admixture shall be Type D as specified in AASHTO M 194.

IV-4-A-2 Assembly and Handling of Materials

IV-4-A-2-1 Assembly of Aggregates

Aggregates shall be assembled in such quantities that sufficient material approved by the Engineer is available to complete any continuous pour necessary for structures. The batching site shall be of adequate size to permit the stockpiling of sufficient, non segregated materials, having proper and uniform moisture content to ensure continuous and uniform operation. Aggregates shall enter the mixer in a manner approved by the Engineer and in such a manner to ensure that no matter foreign to the concrete or matter capable of changing the desired proportions is included. In the event two (2) or more sizes or types of coarse or fine aggregates are used on the same project, only one (1) size or type of each aggregate may be used on one (1) continuous concrete pour.

IV-4-A-2-2 Stockpiling of Aggregates.

All aggregates shall be stockpiled before use in order to prevent segregation of material, to ensure a uniform moisture content, to provide uniform conditions for proportioning plant control and to aid in obtaining concrete that is uniform as to materials and moisture content.

The use of equipment or methods of handling aggregates which results in the degradation of the aggregates is strictly prohibited. Bulldozers with metal tracks shall not be used on coarse aggregate stockpiles. All equipment used for handling aggregates shall be approved by the Engineer.

Stockpiling of aggregates shall be in the manner approved by the Engineer and in addition, every precaution shall be taken to prevent segregation. Segregation shall be prevented by making no layer higher than one and one-half (1.5) meters and if two (2) or more layers are required, each successive layer shall not be allowed to "cone" down over the next lower layer.

Aggregates shall not be stockpiled against the supports of proportioning hoppers and weighing devices.

Aggregates shall be stockpiled and protected at locations which preclude contamination by brackish groundwater during periods of high water or contamination from other sources which might detrimentally affect the aggregates. Contaminated aggregates shall not be used in the concrete.

When required, the aggregate stockpiles shall be sprinkled with water, twelve (12) hours prior to use, to maintain a moisture content in the aggregate equivalent to the water absorption value of the aggregate as determined by AASHTO T 84 and AASHTO T 85.

IV-4-A-2-3 Segregation

Segregated aggregates shall not be used until they have been thoroughly remixed and the resultant pile is of uniform and acceptable gradation at any point from which a representative sample is taken. The Contractor shall remix aggregate piles when ordered by the Engineer.

IV-4-A-2-4 Transporting of Aggregates

If aggregates are to be transported from a central proportioning plant to the mixer in batch-boxes or dump trucks, such equipment shall be of sufficient capacity to carry the full volume of materials for each batch of concrete. Partitions separating batches shall be approved by the Engineer and shall be adequate and effective to prevent spilling from one compartment to another while in transit or being dumped.

IV-4-A-2-5 Cement Storing And Stockpiling

Cement in storage or stockpiled on the site shall be protected from any damage by climatic conditions. Methods of storing or stockpiling shall be approved by the Engineer. Cement shall be transported to the mixer in the original sacks. Each batch shall contain the full amount of cement for the batch. Batches where cement is placed in contact with the aggregates may be rejected unless mixed within one and one-half (1-1/2) hours.

IV-4-A-3 Composition Of Concrete

IV-4-A-3-1 Requirements

The mix proportions shall be selected to ensure that the workability of the fresh concrete is suitable for the conditions of handling and placing, having regard to the structural element being constructed.

The minimum cement contents and maximum water/cement ratios of designed mixes shall be as given in Table 5.1. In the event of sulphate exposure precautions requiring lower cement content than those required for normal conditions the latter requirements shall prevail.

The maximum cement content in any mix shall not exceed 500 kg/m^3 for normal structures and 425 kg/m^3 for liquid retaining structures.

In all cases of mix proportioning, the added water shall be included with due allowance for the moisture contained in the aggregates and shall be the minimum consistent with the workability requirements.

TABLE 5.1 MINIMUM CEMENT CONTENTS

NORMAL CONDITIONS

Type of Structural Element	Exposure Conditions (BS 8110)	Minimum Cement Content (kg/m³)			Maximum water/Cement Ratio
		Maximum Aggregate Size			
		40 mm	20 mm	10 mm	
Liquid Retaining Structures. Shafts and Tunnel Linings	Severe	295	325	356	0.55
All Foundations and Buried Structures	Moderate	270	300	340	0.60
Building Super-Structure	Moderate	270	300	340	0.60

ADDITIONAL REQUIREMENTS WHEN EXPOSED TO SULPHATE CONDITIONS (ALL STRUCTURAL CONCRETE)

Concentration of Sulphates		Type of cement	Minimum Cement Content (Kg/m³) Maximum Aggregate Size			Maximum Water/Cement Ratio
In Soil (Total SO3)	In Ground Water Parts per 100,000		40 mm	20 mm	10 mm	
< 0.2	< 30	OPC	NORMALCONDITIONS			
0.2 - 0.5	30 - 120	OPC SRPC	300 250	330 280	370 320	0.50 0.55
0.5 - 1.0	120 - 250	OPC SRPC	Not Permitted 300	330	370	- 0.50
1.0 - 2.0	250 - 500	OPC SRPC	Not Permitted 340	370	410	- 0.45
> 2.0	> 500	SRPC	Ditto but with protective coating			0.45

IV-4-A-3-1-1 Strength

The characteristic strength of concrete means that value of the 28 day below which 5% of all possible test results would be expected to fall.

The relationship between grade of the concrete and its characteristic strength shall be as given in BS 5328. The grade of concrete to be used in particular locations shall be as given in Table 5.2 unless noted otherwise on the Drawings.

TABLE 5.2 CONCRETE STRENGTH REQUIREMENTS

Location	Maximum Coarse Aggregate Size (mm)	Grade of concrete (BS 5328)
Blinding Concrete		
General Structures	20 or 40	C15P
Liquid Structures	20	C20P
Blinding Concrete		
Sulphate Condition	20	C25P
Substructure thickness less than 400 mm	20	C25P

Location	Maximum Coarse Aggregate Size (mm)	Grade of concrete (BS 5328)
Substructures, walls and slabs more than 400 mm	20	C25P
Superstructures normal		
Concrete	20	C25P
Liquid retaining		
Structures	20	C35A
Fine concrete	10	C25D
Precast concrete	10 or 20	C30D

In the above table suffix P means a prescribed mix, D means a designed mix and A means a design mix complying with the requirements of BS 8007.

IV-4-A-3-2 Mix Proportions & Measurement for Proportioning Materials

The Contractor shall consult with the Engineer as to mix proportions at least forty-five (45) days prior to beginning concrete work. The actual mix proportions of cement, aggregates and water shall be determined by the Contractor under the supervision of the Engineer.

The Contractor shall, in the presence of the Engineer, prepare trial mixes for each class of concrete required for the project, made with the approved materials to be used in the work. The proportions of the trial-mixes shall be such as to produce a dense mixture containing the cement content specified and meeting the plasticity requirements and one hundred fifteen (115) percent of the strength requirements specified for the designated classes of concrete. If the materials supplied by the Contractor are of such a nature or are so graded that proportions based on minimum cement content cannot be used without exceeding the maximum allowable water content, the proportions will be adjusted so as to require the least amount of cement which will produce concrete of the required plasticity and workability without exceeding such allowable water content. No additional payment will be made for increased quantity of cement. Test cylinders shall be made from the trial-mixes.

The Engineer will review the Contractor's trial-mixes and break the test cylinders at seven (7) and twenty-eight (28) days. The Engineer will then determine which of the trial-mixes shall be used. If none of the trial-mixes for a class of concrete meets the specifications, the Engineer will direct the Contractor to prepare additional trial-mixes. No class of concrete shall be prepared or placed until its job-mix proportions have been approved by the Engineer.

The approval of the job-mix proportions by the Engineer or his assistance to the Contractor in establishing those proportions, in no way relieves the Contractor of the responsibility of producing concrete which meets the requirements specified in these specifications.

All costs connected with the preparation of trial-mixes and the design of the job-mixes shall be done by the Contractor, except that the Engineer shall not charge the Contractor for laboratory supervision and the breaking of the test cylinders.

IV-4-A-3-2-1 Measurement for Proportioning Materials

IV-4-A-3-2-1-1 Cement

The cement shall be measured as packed by the manufacturer, a sack of cement shall weigh fifty (50) kilograms. Measurement shall be accurate to within one-half (1/2) percent throughout the range of use.

IV-4-A-3-2-1-2 Water

The mixing water shall be measured by weight or by volume. In either case the measurement shall be accurate to within one (1) percent throughout the range of use.

IV-4-A-3-2-1-3 Aggregates

The aggregates shall be measured by weight. The measurement shall be accurate to within one-half (1/2) percent throughout the range of use.

IV-4-A-3-3 Concrete

IV-4-A-3-3-1 Porous Concrete

Porous concrete shall be composed of ordinary Portland cement and 37.5mm single size aggregate complying with B.S 882,1201: Part 2.

The ratio of aggregate to cement shall be 8:1 by volume or 10:1 by mass.

The concrete shall be mixed by machine or by hand to a uniform color and consistency before placing. The quantity of water used shall not exceed that required to coat all of the aggregate particles without forming excess grout.

The concrete shall be compacted by hand when total thickness does not exceed 40cm, otherwise it shall be compacted by rollers. The placement for roller compaction shall be in layers but shall not exceed 40cm in thickness per layer.

Permeability shall range between 1×10^{-2} and 1×10^{-3} meter/sec.

Compressive strength : 105 Kg/cm².

Contractor shall demonstrate the permeability of porous concrete in place by an effective field testing method that is approved by the Engineer. Contractor shall also install a laboratory on site for testing the permeability of concrete on samples before any placing of porous concrete. The permeability test method shall be approved by the Engineer.

IV-4-A-3-3-2 Cyclopean Concrete

Cyclopean concrete shall consist of Class "C" concrete containing large embedded stones. The embedded rubble stones shall be of approved quality, sound and durable, and free from segregations, seams, cracks and other structural defects or imperfections tending to destroy its resistance to the weather. It shall be free from rounded, worn, or weathered surfaces. All weathered stone shall be rejected. The stone shall be kept free from dirt, oil, or any other injurious material which may prevent proper adhesion. The largest dimension of any rubble stone shall not exceed 20 centimeters. The distance between two adjacent rubble stones or between a rubble stone and the form shall not be less than 5 centimeters.

The stone shall be carefully placed-not dropped or cast-so as to avoid injury to the forms or to the partially set adjacent masonry. All stones shall be washed and saturated with water before placing. The total volume of the stone shall not be greater than one third of the total volume of the portion of the work in which it is placed.

The limiting values which shall govern for each class of concrete are as follows:

The cement content specified herein shall be determined from a yield test in accordance with AASHTO T 121.

Maximum limits shown for liters of water per sack of cement shall include free water in aggregates. Slump shall be tested in accordance with AASHTO T 119.

Concrete for Structures. Cement, water and slump requirements for the various classes of structural concrete are specified in the following table:

		Water per Sack of Cement Including Free Water In Aggregates Maximum		Consistency in Slump	
Class of Concrete	Kilograms of Cement per Cubic Meter of Concrete Minimum	Coarse Aggregate Rounded Liters	Coarse Aggregate Angular Liters	Regular Placing Millimeters	Vibrated Millimeter
A	350	25	26	75-125	25-100
B	350	24	26	75-125	25-100
C	300	24	26		25-75
D	200	24	26		25-75
E	350	25	26	75-125	25-100
K	350	26	28	75-125	25-100

When concrete is proportioned by weight in a central batch plant and consistent compressive test results are maintained, on the basis of ACI 214 "Recommended Practice for Evaluation of Compression Test Results of Field Concrete," mix design proportions may be modified, subject to minimum water-cement ratio requirements, including reduction of cement content. In no case, however, shall the cement content of structural concrete be reduced to less than 6.0 sacks of cement per cubic meter of concrete.

IV-4-A-3-3-3 Changes in Proportion

As the work progresses, the Engineer reserves the right to require the Contractor to change the proportions from time to time if conditions warrant such changes to produce satisfactory results. Any such changes may be made within the limits of the specifications at no additional compensation to the Contractor.

IV-4-A-4 Concrete Strength Requirements

The ultimate compressive strength of concrete as tested at twenty-eight (28) days shall not be less than:

Class	Minimum Compressive Strength At Twenty-Eight (28) Days Kilograms Per Square Centimeter	Maximum Size Aggregate
A	250 Kg/cm²	25 mm (1 inch)
B	250 Kg/cm²	50 mm (2 inch)
C	175 Kg/cm²	63 mm (2-1/2 inch)
D	105 Kg/cm²	63 mm (2-1/2 inch)
E	200 Kg/cm²	50 mm (2 inch)
K	210 Kg/cm²	19 mm (3/4-inch)

The seven (7) day compressive strengths shall not be less than seventy-five (75) percent of the required twenty-eight (28) day strength.

The ultimate compressive strength of the concrete shall be determined on test specimens obtained and prepared in accordance with AASHTO T 23 and AASHTO T 126, except that only six (6) inches [one hundred fifty-two (152) millimeters] by twelve (12) inches [305 millimeters] cylinders shall be used for compression tests. The Contractor shall furnish single use cylinder molds conforming to AASHTO M 205, or when approved by the Engineer, reusable vertical molds made from heavy gauge metal.

IV-4-B SPECIAL TYPES OF CONCRETE

IV-4-B-1 Air Entrained Concrete

Concrete where specified shall include an approved air-entraining agent capable of producing a 5% air-entrainment with a tolerance of 0.5%.

The mix shall be purposely designed having regard for the nature of grading of the aggregates and air-entraining agent being used.

Preference shall be given to the use of air-entraining agents which can be administered in fixed calibrated amounts through a dependable mechanical dispenser or sachet and which are added to the mixing water.

Frequent air meter tests shall be carried out and the consistency of the air-entrainment maintained to the above tolerances by adjustments in the mix, as may be necessary.

IV-4-B-2 Concrete in Benching

Concreting for benching in manholes, pumping stations and works structures shall consist of Grade C25P concrete unless otherwise specified. It shall be placed with low workability to the approximate shape required and, while still green, shall be finished with not less than 20 mm of Grade C25P concrete to a steel trowel led finish and to the contours indicated on the Drawings

IV-4-B-3 Ready Mix Concrete and Central Mixed Concrete

IV-4-B-3-1 Description

“Ready-Mixed Concrete” and “Central-Mixed Concrete” shall consist of a mixture of Portland cement, water and aggregate, without air-entraining or water-reducing admixture. The terms ready-mixed or central-mixed concrete shall include transit-mixed concrete and all will be referred to hereinafter as ready-mixed concrete.

Ready-mixed concrete may be used in the construction of all work, when approved by the Engineer.

Ready-mixed concrete may be manufactured by previously approved commercial plants or by other approved plants furnished for the work.

Approval of any ready-mixed concrete plant will be granted only when an inspection of the plant indicates that the equipment, the method of storing and handling the materials, the production procedures, the transportations and rate of delivery of concrete from the plant to the point of use, all meet the requirements set forth herein.

Permission to use ready-mixed concrete from any previously approved plant may be rescinded at any time upon failure to comply with the requirements of the specifications.

Ready-mixed concrete shall be mixed and delivered to the point of use by means of one of the following combinations of operations:

Mixed completely in a stationary central-mixing plant and the mixed concrete transported to the point of use in a truck mixer or tank agitator operating at agitator speed, or when approved by the Engineer, in non-agitating equipment (known as "Central-Mixed Concrete").

Mixed completely in a truck mixer at the batching plant or while in transit (known as transit-mixed concrete).

Mixed completely in a truck mixer at the point of use following the addition of mixing water (known as truck-mixed concrete).

IV-4-B-3-2 Materials

All materials used in the manufacture of ready-mixed concrete shall conform to the requirements of "Concrete section".

IV-4-B-3-3 Equipment

IV-4-B-3-3-1 General

Equipment shall be of the type and number as outlined in the Contractor's Program of Work, as approved by the Engineer.

IV-4-B-3-3-2 Check Tests

The Engineer may, from time to time, make slump tests of individual samples of the concrete at approximately the beginning, the mid-point and end of discharging the load. If the slumps vary by more than the allowable tolerance as specified in the specifications, the mixer or agitator shall not be used unless the condition is corrected to the satisfaction of the Engineer. All mechanical details of the mixer or agitator such as water measuring and discharge apparatus, condition of the blades, speed of rotation of the drum, general mechanical condition of the unit and clearance of the drum shall be checked before further use of the unit will be permitted.

IV-4-B-3-3-3 Inspection

Mixers and Agitators shall be examined periodically for changes in condition due to accumulation of hard concrete or mortar or to wear of blades. The mixers shall be cleaned at intervals approved by the Engineer. The pick-up and throw-over blades in the drum or drums shall be repaired or replaced when they are worn down twenty (20) millimeters or more. The Contractor shall:

Have available at the job site a copy of the manufacturer's design, showing dimensions and arrangements of blades in reference to original height and depth, or provide permanent marks on the blades to show points of twenty (20) millimeter wear from new conditions. Drilled holes of six (6) millimeter diameter near each end and at midpoint of each blade are recommended.

Truck mixers and agitators of the revolving-drum type must be equipped with a hatch in the periphery of the drum shell of such design as to permit access to the inside of the drum for inspection, cleaning and repair of the drum and blades.

IV-4-B-3-4 Composition of concrete

The composition of ready-mixed concrete shall conform to the requirements of "Concrete section".

IV-4-B-4 Pneumatically Applied Mortar

IV-4-B-4-1 Description

This work shall consist of the furnishing and placing of pneumatically applied mortar for the construction of portions of structures, repairing concrete structures, texturing concrete surfaces, encasement of structural steel members, lining ditches and channels, paving slopes and for other miscellaneous work, all as shown on the plans.

This work also includes the preparation of surfaces to receive the mortar and the furnishing and placing of any reinforcement steel and anchors for reinforcement.

Pneumatically applied mortar shall consist of either dry mixed fine aggregate and Portland cement pneumatically applied by a suitable mechanism, to which mixture the water is added immediately previous to its expulsion from the nozzle, this process being referred to as the dry mix process, or mortar premixed by mechanical methods and pneumatically applied through a nozzle onto the prepared surface, this process being referred to as the wet mix process.

IV-4-B-4-2 Materials

Aggregate shall be fine aggregate, except that up to 30 percent coarse aggregate, conforming to AASHTO M43 for size 3/8 inch to No. 8 or No. 16, reproduced herein below, may be substituted for fine aggregate requirements :

Gradation (3/8" to No. 8)

Standard sieve size	Percent passing (by weight)
1/2"	100
3/8"	85 - 100
No. 4	10 - 30
No. 8	0 - 10
No. 16	0 – 5

Gradation (3/8" to No. 16)

Standard sieve size	Percent passing (by weight)
1/2"	100
3/8"	90 - 100
No. 4	20 - 55
No. 8	5 - 30
No. 16	0 - 10
No. 50	0 – 5

Welded Wire Fabrics : Welded wire fabric shall conform to ASTM A185 and shall be galvanized in accordance with ASTM A385 and A641. Mesh and wire size shall be as follows : either 2 x 2 - W1 x W1 or 3 x 3 - W1.5 x W1.5.

Anchor bolts or studs : Anchor studs used to support reinforcing wire fabric or bars when placing mortar against existing concrete or rock shall consist of 1/4 inch minimum diameter expansion hook bolts placed in drilled holes. Each bolt shall have sufficient engagement in sound masonry to resist a pull-out force of 150 lbs.

When permitted by the Engineer, driven steel studs of not less than 1/8 inch diameter and a minimum length of 2 inches may be used. The equipment used for driving such studs shall be of the type which uses an explosive for the driving force, and shall be capable of inserting the stud or pin to the required depth without damage to the surrounding concrete.

IV-4-B-4-3 Proportioning and Mixing

IV-4-B-4-3-1 Proportioning

The Contractor shall submit the proposed mix design to the Engineer for approval prior to the start of the work.

Unless otherwise specified, the mix design shall provide a cement to aggregate ratio, based on dry loose volumes, of not less than 1:35 for the construction and repair of concrete structures and for encasing steel members, or not less than 1:5 for lining ditches and channels and for paving slopes.

The water content shall be as low as practical and shall be adjusted so that the mix is sufficiently wet to adhere properly and sufficiently dry so that it will not sag or fall from vertical or inclined surfaces or separate in horizontal work.

IV-4-B-4-3-2 Mixing

Mixing shall be done either by the dry mix or wet mix process. Before being charged into the placing equipment, the materials shall be thoroughly and uniformly mixed using a mixer designed for use with pneumatic application. It may be either a paddle type or drum type mixer. Transit mix equipment and methods may be used for the wet process.

IV-4-B-4-4 Preparation of Surfaces

IV-4-B-4-4-1 Earth surfaces

Unless otherwise specified, the surface shall be compacted to 95% of the maximum density as determined by AASHTO T 180-74 Method D. The earth surface is then trimmed to line and grade to assure the design thickness of shotcrete. Prior to applying mortar the surface shall be dampened by water spraying. The amount of predampening depends on the absorption qualities of the earth. Puddling, ponding or leaving free standing water on the surface will not be permitted.

IV-4-B-4-4-2 Concrete, Masonry or Rock Surfaces

All unsound material shall be removed before applying the mortar. Any area to be repaired shall be chipped or scarified to remove offsets which would cause an abrupt change in thickness without suitable reinforcement.

Edges shall be tapered to leave no square shoulders at the perimeter of a cavity. All spalled, severely cracked, deteriorated, loose and unsound concrete surface shall be completely removed by chipping, scarifying, sandblasting water blasting or other mechanical methods.

Where mortar is to be placed against a smooth concrete surface, the surface shall be roughened by sandblasting, bush hammering or by other suitable mechanical means.

Rock surfaces shall be cleaned of loose materials, mud and other foreign matter that will prevent bond of mortar.

The surface against which mortar is to be placed shall be kept wet for at least one hour and then allowed to dry to a surface dry condition just prior to application of the mortar.

IV-4-B-4-4-3 Steel

Rust, oil, scale and previously applied paint shall be removed from steel surfaces receiving the mortar.

IV-4-B-4-5 Placement of Welded Wire Fabric

The mesh shall be cut to proper size and carefully bent so as to follow the contour of the areas to receive the mortar. The reinforcing mesh shall be securely tied with 16 gage (1.6 mm) or heavier tie wire to preset anchors. Large knots of tie wire shall be avoided to minimize the formation of sand pockets and voids. When sheets of mesh intersect, they shall be lapped at least one and one half spaces in both directions and be securely fastened. When more than one layer of mesh is required, the first layer shall be covered with mortar before placing the next mesh. The anchor or tie shall extend to the second layer. Unless specified otherwise the sheet of mesh shall be placed in the center of the mortar layer. Fabric supported adjacent to the prepared surface shall not

be closer than 1.25 cm to said surface. When mesh and bars are used together in combination, the mesh shall be placed exterior to the bars.

Anchors used to attach the wire fabric to concrete, masonry or rock shall be spaced no more than 30 centimeters, center to center, on overhead surfaces; 45 centimeters, center to center, on vertical surfaces; and 90 centimeters, center to center, on top of horizontal surfaces. At least three anchors shall be used in each individual patch area.

All steel items, including anchors, reinforcing bars and wire fabric, shall be no closer than 2.5 cm to the finished surface of the mortar.

IV-4-B-4-6 Forms and Ground Wires

The forms, when used shall be constructed so as to permit the escape of air and rebound. Ground wires or other accepted means shall be used to establish the thickness, surface planes, and finish lines of the shotcrete. Ground wires shall be located at intervals sufficient to ensure proper thickness throughout. Wires shall be stretched tight and shall not be removed prior to application of the finish coat.

Headers will be required where the plans indicate a formed edge or joint.

IV-4-B-4-7 Application of Mortar

Only experienced foremen, gunmen, nozzlemen and rodmen shall be employed, and satisfactory evidence of such experience shall be furnished when requested by the Engineer.

The mortar shall be applied by pneumatic equipment that sprays the mix onto the prepared surface at high velocity as needed to produce a compacted dense homogeneous mass. The air compressor and delivery hose lines shall be of adequate capacity and size to provide a minimum pressure of 35 psi at the nozzle for one inch nozzles and proportionally greater for larger nozzles. The velocity of the material as it leaves the nozzle must be maintained uniform at a rate determined for the given job condition to produce minimum rebound.

Water which is added to the nozzle shall be supplied at a uniform pressure of not less than 15 psi greater than the air pressure at the nozzle.

The mortar shall be applied as dry as possible to prevent shrinkage cracking. Shooting strips shall be employed to ensure square corners, straight lines and a plane surface of mortar, except as otherwise permitted by the plans or approved by the Engineer.

They shall be so placed as to keep the trapping of rebound at a minimum. At the end of each day's work, or similar stopping periods requiring construction joints, the mortar shall be sloped off to a thin edge. Before placing an adjacent section, construction joints shall be thoroughly cleaned and wetted as required or directed by the Engineer. In shooting all surfaces, the stream of flowing material from the nozzle shall impinge as nearly as possible at right angles to the surface being covered, and the nozzle shall be held from 60 to 120 cm from the working surface.

A sufficient number of mortar coats shall be applied to obtain the required thickness. On vertical and overhead surfaces, the thickness of each coat shall be not greater than 2.5 cm, except as approved by the Engineer, and shall be placed so that it will neither sag nor decrease the bond of the preceding coat. The time interval between successive layers in sloping, vertical or overhanging work shall be sufficient to allow initial but not final set to develop. At the time the initial set is developing, the surface shall be cleaned to remove the thin film of laitance in order to provide for a bond with succeeding applications.

Rebound or accumulated loose sand shall be removed from the surface to be covered prior to placing of the original or succeeding layers of mortar and shall not be embedded in the work.

Materials that have been mixed for more than 45 minutes and have not been incorporated in the work shall not be used, unless otherwise permitted by the Engineer.

After curing and before final acceptance all repaired areas shall be sounded. All unsound and cracked areas shall be removed and replaced. The Engineer reserves the right to order the removal of defective mortar and its replacement with an acceptable mortar without additional cost to the Employer. Any remedial measure ordered by the Engineer to correct defective mortar shall be at the expense of the Contractor.

IV-4-B-4-8 Joints

IV-4-B-4-8-1 Construction joints

Construction joints shall be tapered to a shallow edge form about 25 mm thick, except where the joint will be subject to compressive stress. In this case the joint shall not be tapered and special care shall be taken to avoid or remove trapped rebound at the joint.

The entire joint shall be thoroughly cleaned and wetted prior to the application of additional mortar. Joints shall be perpendicular to the main reinforcement. Reinforcement shall be continued across joints.

IV-4-B-4-8-2 Other joints

Joints shall be installed in accordance with Contract documents. Reinforcement or other embedded metal items, which are bonded to the mortar shall be extended continuously through control joints.

IV-4-B-4-9 Weather Limitations

Pneumatically placed mortar shall not be placed on a frozen surface nor when the ambient temperature is less than 5°C, nor shall it be placed when it is anticipated that the temperature during the following 24 hours will drop below 0°C.

The application of pneumatically placed mortar shall be suspended if high winds prevent proper application, or rain occurs which would wash out the pneumatically placed mortar.

IV-4-B-4-10 Protection of Adjacent Work

During progress of work, where appearance is important, adjacent facilities which may be permanently discolored, stained or otherwise damaged by over spray, dust or rebound, shall be adequately protected and, if contacted, shall be cleaned by early scraping, brushing or washing, as the surrounding permit.

IV-4-B-4-11 Finishing

After mortar has been placed to desired thickness, all high spots shall be cut off with a sharp trowel, or screeded to a true plane as determined by shooting strips or by the original masonry surface, or as directed.

Cutting screeds, where used, shall be lightly applied to all surfaces so as not to disturb the mortar for an appreciable depth, and they shall be worked in an upward direction when applied on vertical surfaces. Unless otherwise directed, the finished mortar surface shall be given a final flash coat of about 3 mm of mortar. Special care shall be taken to obtain a uniform appearance on all exposed surfaces.

IV-4-B-4-12 Curing and Protecting

Pneumatically placed mortar shall be water cured. The minimum water curing duration shall be 96 hours. The mortar shall be protected from freezing during the curing period.

IV-4-B-5 Pumped Concrete

Where pumping of concrete is permitted to be used, no relaxation of the requirements of this Specification will be permitted. Particular attention shall be paid to the proper grading of aggregates to prevent bleeding and/or segregation during the pumping operations. The inclusion of water-reducing additives or other materials including fly ash to improve the flow characteristics of the concrete will only be permitted where it can be shown that they do not adversely affect the concrete either in the plastic phase or in the finished work

IV-4-C REINFORCING STEEL

IV-4-C-1 Description

This Work shall consist of furnishing and placing reinforcing steel in accordance with the specifications and in conformity with the plans.

IV-4-C-2 Materials

IV-4-C-2-1 Reinforcing Bars

IV-4-C-2-1-1 Type

All reinforcing bars shall be of a deformed type in accordance with AASHTO M 31, except that plain bars may be used where specifically indicated on the drawings.

IV-4-C-2-1-2 Quality

All steel reinforcement shall conform to the requirements of AASHTO M 31, Grade 60 unless otherwise shown on the plans or specified.

IV-4-C-2-2 Certification and Identification

IV-4-C-2-2-1 Certification

Three (3) copies of a mill test report shall be furnished to the Engineer for each lot of billet-steel reinforcement bars proposed for use on the project. The mill test report shall be sworn to for the manufacturer of the steel by a person having legal authority to bind the manufacturer and shall show the following information:

The process or processes used in the manufacture of the steel from which the bars were rolled.

Identification of each heat of open-hearth, basic oxygen or electric furnace and/or each lot of acid Bessemer steel from which the bars are rolled.

Chemical and physical properties of the heat from which the bars were rolled.

IV-4-C-2-2-2 Identification

The bars in each lot shall be legibly tagged by the manufacturer and/or fabricator before being offered for inspection. The tag shall show the manufacturer's test number and lot number or other designation that will identify the material with the certificate issued for that lot of steel.

The fabricator shall furnish three (3) copies of a certification which shows the heat number or numbers from which each size of bar in the shipment was fabricated.

IV-4-C-2-2-3 Inspection and Sampling

The sampling and testing of reinforcement bars may be made at the source of supply when the quantity to be shipped or other conditions warrant such inspection. Bars not inspected before shipment will be inspected after arrival on the work. Test samples obtained at the destination of the steel shall be duplicate bars not less than one (1) meter in length and bars from which such samples are taken shall be replaced at the Contractor's expense. The Engineer reserves the right to resample and inspect all reinforcement steel upon its arrival at the work site.

All reinforcement bars shall be free from detrimental dirt, mill scale, rust, paint, grease, oil or other foreign substance, fins or tears. The Contractor will not be required to remove slight rusting which discolors the metal, but he shall remove all loose mill scale and scales rust. Brushing to clean blue metal will not be required. There shall be no evidence of piping or visual flaw in the test specimen or on the sheared ends of the bars.

Supports. Metal supports, approved by the Engineer, shall be provided and used to retain the reinforcement at proper distances from the forms. Supports under horizontal bars at the bottom of the deck slabs shall be spaced at not more than eighty (80) diameters of the bar. All reinforcement shall be so rigidly supported and fastened that displacement will not occur during construction. Reinforcing steel shall be inspected in place and must be approved by the Engineer before any concrete is deposited.

IV-4-C-2-2-4 Welded Wire Fabric

To be used for the reinforcement of concrete shall conform to the following requirements:

IV-4-C-2-2-5 Dimensions

Welded steel wire fabric shall conform to the size and dimensions shown on the plans.

IV-4-C-2-2-6 Properties

Wire fabric furnished shall conform to the requirements for "Welded Steel Wire Fabric for Concrete Reinforcement," AASHTO M 55.

IV-4-C-3 Construction Requirements

IV-4-C-3-1 Protection and Storage

Reinforcing steel shall be protected at all times from damage. Reinforcing steel shall be stored above the ground on platforms, skids, or other supports. It shall be stored in such a manner and adequately marked to facilitate inspection and checking. When placed in the Work, the reinforcing steel shall be free from dirt, detrimental scale, paint, oil or other foreign substance.

IV-4-C-3-2 Cutting and Bending

All cutting and bending of reinforcement bars shall be done by competent workmen and with equipment approved by the Engineer. Unless shown otherwise on the plans or unless written approval is obtained from the Engineer, all reinforcement bars shall be cut and bent in an on-site fabrication shop.

Bent bar reinforcement shall be cold bent to the shapes shown on the plans, and unless otherwise provided on the plans or by written authorization of the Engineer, bends shall conform to the following requirements:

D = 6d for five (5) millimeter through twenty-two (22) millimeter bar sizes

D = 8d for twenty-four (24) millimeter through twenty-eight (28) millimeter bar sizes

D = 10d for thirty (30) millimeter and over bar sizes

Where D = Minimum pin diameter around which a bar may be bent d = Bar diameter

IV-4-C-3-3 Placing, Supporting and Fastening

All reinforcing steel shall be accurately placed and, during the placing of concrete, firmly held by approved supports in the position shown on the plans. Reinforcing bars shall be securely fastened together. Reinforcement placed in any member shall be inspected and approved before any concrete is placed. Laying or driving bars into the concrete after placement will not be permitted. All horizontal reinforcement shall be supported on metal supports or spacers as approved by the Engineer. The use of small stones or wood blocks for supporting reinforcement will not be permitted. The reinforcement shall be held securely in place at the proper position and spacing as indicated on the plans by the use of wire ties at bar intersections and tying to the supports and spacers. The adequacy of the supports and ties to secure the reinforcement properly shall be subject to the approval of the Engineer.

IV-4-C-3-4 Splicing

Splices shall be avoided at points of maximum stress. They shall, where possible, be staggered, and shall be designed to develop the strength of the bar without exceeding the allowable unit bond stress. Unless otherwise shown on the plans, bars in the bottom of beams and girders, and in walls, columns, and haunches shall be lapped a minimum of twenty (20) diameters and bars near the top of beams and girders having more than thirty (30) centimeters of concrete under. The bars shall be lapped a minimum of thirty-five (35) diameters to make the splice. In no case shall bars be lapped less than thirty (30) centimeters.

IV-4-C-3-5 Couplers

Couplers for reinforcement shall be either Standard Swaged Splices or Type II Alpha Couplers manufactured by CCL Systems Limited, Cabco House, Ewell Road, Surbiton, Surrey England, KT9 7AH, UK., or similar approved. Where bars of different diameters are to be joined a CCL Reducer Sleeve or similar shall be used.

Couplers shall be suitable for the type and size of reinforcing bars and shall be capable of developing 115% of the characteristic strength of the smaller of the reinforcing bars being joined in both tension and compression. Couplers shall be installed in accordance with the manufacturer's recommendations. Square twisted reinforcing bars shall not be used with couplers.

IV-4-C-3-6 Reinforcing Bar Trusses

Bar trusses shall be placed, supported and secured in proper position before beginning the placement of the concrete. Unless the bar trusses are so designed and fabricated with outstanding legs to be in contact with the forms they shall be supported on metal supports and spacers. If the weight of the trusses cause the supporting legs of trusses to indent into the forms, bar supports shall be used as auxiliary support for the truss legs.

IV-4-C-3-7 Mesh Reinforcement for Structures

Mesh reinforcement shall be of the sizes and spacing of bars and sheets as shown on the plans. The sheets of mesh shall be lapped as indicated on the plans. The method of placing the mesh and securing it in proper position shall be approved by the Engineer.

IV-4-D CONCRETE STRUCTURE CONSTRUCTION

IV-4-D-1 Description

This Work shall consist of furnishing and placing Portland cement concrete for structures and incidental construction in accordance with the specifications and in conformity with the lines, grades and dimensions as shown on the plans or established by the Engineer.

IV-4-D-2 Construction Requirements

IV-4-D-2-1 Falsework

Detailed plans for falsework and centering shall be prepared by the Contractor and submitted to the Engineer for approval. The plans must be approved by the Engineer before the Work is started.

Falsework and centering shall be designed and constructed to provide the necessary rigidity to support all loads placed upon it without appreciable settlement or deformation. Falsework columns shall be supported on wood or metal bases when it cannot be founded on rock, shale, or thick deposits of other compact material in their natural bed. Falsework shall not be supported on any part of the structure, except the footings, without the written permission of the Engineer. The number and spacing of falsework columns, the adequacy of sills, caps and stringers and the amount of bracing in the falsework framing shall be subject to approval of the Engineer.

Falsework and centering shall be designed and constructed to support the total anticipated loads with a deflection not to exceed two one-thousandths (0.002) of the falsework span. The Contractor shall submit calculations to support this requirement for all spans over three (3) meters and other spans if requested by the Engineer.

All timber shall be of sound wood, in good condition and free from defects that might impair its strength. If the vertical members are of insufficient length to cap at the desired elevation for the horizontal members, they shall preferably be capped and frames constructed to the proper elevation. Ends of the vertical members shall be cut square for full bearing to preclude the use of wedges. If vertical splices are necessary, the abutting members shall be of the same approximate size, the ends shall be cut square for full bearing and the splices shall be scabbed in a manner approved by the Engineer.

The Contractor shall provide means for accurately measuring settlement in falsework during placement of concrete and shall provide a competent observer to observe and correct the settlement.

In designing forms and centering, concrete shall be regarded as a liquid. In computing vertical loads, a weight of twenty-four hundred (2,400) kilograms per cubic meter shall be assumed, and not less than thirteen hundred and sixty (1,360) kilograms per cubic meter shall be assumed in computing horizontal pressure.

The Engineer may refuse permission to proceed with other phases of the work if he deems the falsework unsafe or inadequate to support properly the loads to which it will be subjected.

The review or approval of falsework plans by the Engineer or permission to proceed with the work shall not relieve the Contractor of the responsibility for successful erection or satisfactory results.

IV-4-D-2-2 Formwork

Forms shall be mortar tight and sufficiently rigid to prevent distortion due to the pressure of the concrete and other loads incidental to the construction operations, including vibration. Forms shall be constructed and maintained so as to prevent the opening of joints due to shrinkage of the lumber. They shall be designed to permit easy removal without injury to the concrete. Form lining such as smooth, exterior grade plywood or other approved material shall be used for all formed surfaces. The Contractor shall submit samples, specifications and other pertinent information thereon to the Engineer and secure his prior written permission to use the form lining.

Form lining material shall not bulge, warp or blister, nor shall it stain the concrete. Form lining shall be used in the largest practicable panels to minimize joints. Small panels of the lining material shall not be permitted. The joints in the lining shall be tight and smoothly cut. Adjacent panels of form lining shall be so placed that the grain of the wood will be in the same general direction (all horizontal or all vertical). Thin metal form lining will not be permitted. Undressed lumber of uniform thickness may be used for backing for form lining. Wooden ply form, of adequate thickness, which is properly supported, may be used in lieu of the lined forms specified herein.

Forms shall be maintained after erection to eliminate warping and shrinkage. They shall be checked for dimensions and condition immediately prior to the placement of concrete. The Engineer may at any time require the revision or reconstruction of forms and may refuse permission to place concrete within the forms until they are satisfactorily constructed. If, at any period of the work during or after placing the concrete, the forms show signs of sagging or bulging, the concrete shall be removed to the extent directed by the Engineer, the forms brought to the proper position and new concrete placed. No allowance will be made to the Contractor for such extra work.

Metal forms may be used and are subject to the same requirements and approvals specified for wood forms. The specifications for wood forms with respect to design, mortar tightness, filleted corners, beveled projections, bracing, alignment, removal, reuse and oiling, also apply to metal forms. The metal used for forms shall be of such thickness that the forms will remain true to shape. All bolt and rivet heads shall be countersunk. Clamps, pins of other connecting devices shall be designed to hold the forms rigidly together and to allow removal without injury to the concrete. Metal forms which do not present a smooth surface or do not line up properly shall not be used. Care shall be exercised to keep metal forms free from rust, grease or other foreign matter. Under such circumstances the continuance of use of the metal forms will depend upon satisfactory performance and their discontinuance may be required at any time by the Engineer. Steel panels with metal frames and wood or combination facing which leave permanent impressions or ridges will not be approved.

The inside of all forms shall be oiled with a light, clear, paraffin base oil that will not discolor or otherwise injure the surface of the concrete.

The oiling shall be done where possible after the completion of the forms and prior to placement of reinforcement.

Unless otherwise directed, the exterior side of all forms shall be painted with an approved, good quality high gloss white oil base enamel prior to placing concrete. When complete coverage is not obtained with one (1) coat, the Engineer will order additional coats as he deems necessary to obtain complete coverage. Forms shall be repainted when ordered by the Engineer.

Shrinkage cracks shall be closed by moistening the forms with water prior to concrete placement.

Forms that are to be reused shall be thoroughly cleaned and roiled and, if necessary, shall be reconditioned by revision or reconstruction. Unsatisfactory lumber will be condemned by the Engineer, and shall be removed from the site.

The width and thickness of the lumber, the size and spacing of studs and wales shall be determined with due regard to the nature of the work and shall be sufficient to ensure rigidity of the forms and to prevent distortion due to the pressure of the concrete.

Form bolts, rods or ties shall be made of steel. They shall be the type which permits the major part of the tie to remain permanently in the structure. They shall be held in place by devices attached to the wales capable of developing the strength of the ties. The Engineer may permit the use of wire ties on irregular sections and incidental construction if the concrete pressures are nominal and the form alignment is maintained by other means. The ties shall be removed on all exposed surfaces. The ties shall be removed to a depth of at least fifteen (15) millimeters below the concrete surface. Wire ties shall be cut back at least six (6) millimeters below the concrete surface. The cavities shall be filled with cement mortar composed of one (1) part by volume of cement and two (2) parts of sand and the surface left sound, smooth, even and uniform in color. Sufficient white Portland cement shall be mixed with the cement in the mortar, so when dry, the color will match the surrounding concrete. Form ties will not be permitted through forms for handrail. Pipe spreaders shall not be used unless they can be removed as the concrete is placed, as determined by the Engineer. Wood or metal spreaders shall be removed as the concrete is placed. The use of cofferdam braces or struts that extend through the forms for any concrete section will not be permitted except in unusual situations and then only with the approval of the Engineer.

Where the bottom of the forms is inaccessible, the lower form boards shall be left loose or other provisions made so that extraneous material may be removed from the forms immediately before placing the concrete.

Unless provided otherwise on the plans or directed by the Engineer, all exposed edges shall be beveled by using dressed, mill-cut, triangular molding, having twenty (20) millimeter sides.

All curved surfaces shall be formed with approved plywood or steel.

When instructed by the Engineer the Contractor shall submit formwork drawings and calculations to the Engineer in advance of the concreting.

Formwork shall be of such accuracy, strength and rigidity as to carry the weight and pressure from the concrete to be placed on or against it. together with all constructional wind or other loads likely to be imparted to it, without producing deformation of the finished concrete in excess of the specified tolerances.

Formwork shall be sufficiently tight without plugging to prevent loss of grout during the vibration of the concrete. When required by the Engineer joints between formwork facing boards shall be sealed with foam rubber sealing strips or other approved material.

Faces of formwork shall be clean, free from projecting nails adhering grout and other imperfections or defects. Formwork shall be treated with approved mould oil before positioning. The contractor shall prevent reinforcement or steelwork from being contaminated by the oil.

Formwork, which as a result of prolonged use or general deterioration or is otherwise in the opinion of the Engineer unsuitable shall not be used.

Through-bolts or ties will not be permitted in liquid-retaining structures. The Contractor shall use only such bolts or ties as are capable of being removed in whole or in part so that no part remaining embedded in the concrete shall be nearer the surface of the concrete than the specified thickness of cover to the reinforcement.

Beam soffits shall be erected with an upward camber of 5 mm for each 3 meters of span.

Top formwork shall be counterweighted or otherwise anchored against flotation.

Boxes for forming holes shall be constructed so as to be easily removable without damaging the concrete during removal. They shall be properly vented to permit the escape of entrapped air, and shall be capable of being sealed, subsequently to prevent the loss of grout.

On all external arises of the concrete 25 mm chamfers shall be formed.

Any openings provided in formwork for inspection and for cleaning-out shall be formed so that they can conveniently closed before the placing of concrete.

All props shall be supported on adequate sole plates and shall not bear directly on or against concrete. They shall be capable of being released gently and without shock to the formwork. No appliance for supporting the formwork shall be built into the permanent structure without the Engineer's prior approval. Props for upper level support shall be placed directly over those at lower levels. Props shall only bear upon work sufficiently mature to carry the load.

Formwork shall be such as to allow for its removal without damaging the concrete and in the case of suspended floors for the removal of the beam sides and slab soffits without disturbing the beam-bottom boards and their props.

Before concreting, the areas which are intended to receive the concrete shall be cleaned by jetting with compressed air and all water and extraneous material removed.

Where timber is used for formwork it shall be properly cured free from warp straight, clean and free from loose knots.

Where metal forms are used for formwork they shall be of the type strengthened by intermediate ribs or cross bracing.

Moving formwork man be used if the Engineer sees it appropriate.

IV-4-D-2-2-1 Sawn Formwork:

Sawn formwork shall be properly designed and constructed of closely-jointed Sawn boards sheet metal or other approved material. It shall produce a standard of finish free from substantial voids, hones-combing or other large blemishes. There shall be no loss of grout.

IV-4-D-2-2-2 Wrought Formwork

All exposed concrete shall be formed by wrought formwork.

Wrought formwork shall produce a high standard of finish with a hard smooth surface with true clean arises. Only minor surface blemishes shall be permitted. The face in contact with the concrete shall consist of framed plywood or metal panels or other approved material. Joints between boards and/or panels shall be arranged in a uniform pattern.

IV-4-D-2-3 Tolerances

Unless otherwise indicated on the Drawings, the tolerances of the finished concrete with respect to the dimensions shown on the Drawings shall not exceed the limits set out in the following Table. Formwork shall be constructed to ensure completed work within the following tolerance limits:

Departure from established alignment	0.5 cm
Departure from established grade	0.5 cm
Variations from plumb or specified batter in lines and surfaces of columns, piers and walls	0.5 cm in 3 meters, if exposed 0.5 cm in 3 meters, if backfilled
Variations from level or indicated grade in slabs, beams, etc.	0.5 cm in 3 meters, if exposed 0.5 cm in 3 meters, if backfilled
Variation in cross-sectional dimensions of columns, piers, slabs, walls, beams	-0.5cm, + 0.5cm
Variations in slab thickness	-0.5cm, + 0.5cm
Footings: Plan Dimensions	-0.5cm, +0.5cm
Eccentricity	2 percent of footing width, not exceeding 5 cm
Reduction in thickness	2 percent of specified thickness

IV-4-D-2-4 Removal of Forms and Falsework

To facilitate finishing, forms on handrails, ornamental work and other vertical surfaces that require a rubbed finish shall be removed as soon as the concrete has hardened sufficiently that it will not be injured as determined by the Engineer. In determining the time for the removal of forms, consideration shall be given to the location and character of the structure, weather and other conditions influencing the setting of the concrete.

If removal of forms or falsework is not controlled by beams or cylinders cured with and under the same conditions as the structure, the following periods, exclusive of periods when the temperature is less than four (4) degrees C, for releasing of forms and supports shall be used as a minimum:

Arch Center 14 days

Centering Under Beams 14 days

Supports Under Flat Slabs 14 days

Floor Slabs 14 days

Vertical Wall Surfaces 24 hours

Columns 24 hours

Sides of Beams 24 hours

Top Slabs R.C., Box Culverts 14 days

If high early strength cement is used, the time limits may be decreased as determined by the Engineer.

When form and falsework removal is controlled by beams or cylinders cured with, and under the same conditions as the structure, the release of falsework in load or movement carrying members shall not occur until the concrete has reached its specified strength. In no case shall release be permitted in less than seven (7) days.

Methods of form removal likely to cause overstressing of the concrete shall not be used. In general, the forms shall be removed from the bottom upwards. Supports shall be removed in such a manner as to permit the concrete to uniformly and gradually take the stresses due to its own weight.

In general, arch centering shall be struck and the arch made self-supporting before the railing or coping is placed. For filled spandrel arches, such portions of the spandrel walls shall be left for construction subsequent to the striking of centers, as may be necessary to avoid jamming of the expansion joints. In arch structures of two or more spans, the sequence of striking centers shall be as specified or approved.

Immediately after the removal of the forms, all fins caused by form joints and other projections shall be removed and all pockets cleaned and filled with a cement mortar composed of one (1) part by volume of Portland cement and two (2) parts sand. Sufficient white Portland cement shall be mixed with the cement in the mortar, so that when dry, the color will match the surrounding concrete. Patches shall be moistened prior to mortaring to obtain good bond with the concrete. When directed by the Engineer, the Contractor shall at his own expense, substitute an approved epoxy grout for the Portland cement mortar or provide an epoxy bonding agent to be used in conjunction with the Portland cement mortar. If, in the judgment of the Engineer, rock pockets are of such extent or character as to materially affect the strength of the structure or to endanger the life of the steel reinforcement, he may declare the concrete defective and require the removal and replacement of that portion of the structure affected. The resulting surfaces shall be true and uniform. Portions of the structure which cannot be finished or properly repaired to the satisfaction of the Engineer shall be removed.

IV-4-D-2-5 Mixing and Transporting

IV-4-D-2-5-1 Mixing

Concrete shall be mixed in quantities required for immediate use. Concrete shall not be used which has developed initial set or is not in place one-half (1/2) hour after the water has been added for non-agitated concrete or if agitated, the concrete must be in place one and one-half (1-1/2) hours after the water has been added. Retempering concrete by adding water or by other means will not be permitted. Concrete that is not within the specified slump limits at the time of placement shall not be used and shall be disposed of as directed by the Engineer.

The Concrete may be mixed at the site of the work, in a central-mix plant, or in truck mixers. The mixer shall be of an approved type and capacity. Mixing time shall be measured from the time all materials, except water, are in the drum. Ready-mixed concrete shall be mixed and delivered in accordance with requirements of Section 3.3 "Ready-Mixed Concrete and Central-Mixed Concrete".

When mixed at the site of the Work or in a central-mixing plant, the mixing time shall not be less than fifty (50) seconds nor more than ninety (90) seconds. Four (4) seconds shall be added to the specified mixing time if timing starts the instant the skip reaches its maximum raised position. Mixing time ends when the discharge chute opens. Transfer time in multiple drum mixers is included in mixing time. The contents of an individual mixer drum shall be removed before a succeeding batch is emptied therein.

The mixer shall be operated at a drum speed as shown on the manufacturer's nameplate on the approved mixer. Any concrete which, in the opinion of the Engineer, is mixed more or less than the specified time shall be discarded and disposed of by the Contractor at his expense. The volume of concrete mixed per batch shall not exceed the mixer's nominal capacity in cubic meters, as shown on the manufacturer's standard rating plate on the mixer; except that an overload up to ten (10) percent above the mixer's nominal capacity may be permitted when approved by the Engineer, provided concrete test data for strength, segregation and uniform consistency are satisfactory, and provided no spillage of concrete takes place.

The batch shall be so charged into the drum that a portion of the mixing water shall enter in advance of the cement and aggregates. The flow of water shall be uniform and all water shall be in the drum by the end of the first fifteen (15) seconds of the mixing period. The throat of the drum shall be kept free of such accumulations as may restrict the free flow of materials into the drum.

IV-4-D-2-5-2 Central-Mixing

Plants for concrete shall comply with the following requirements, in addition to those set forth above:

IV-4-D-2-5-3 Cement

Means provided for storing cement shall be as approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of unapproved cement before starting to manufacture concrete for the work.

IV-4-D-2-5-4 Aggregate

Coarse and fine aggregate to be used in concrete shall be kept in stockpiles and bins apart from aggregate used in other work. Aggregates shall come from a source approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of unapproved aggregate before starting to manufacture concrete for the work.

IV-4-D-2-5-5 Consistency

The Contractor shall be responsible for producing a concrete that will be of the proper consistency when delivered to the job site.

IV-4-D-2-5-6 Hauling

Mixed concrete from the central-mixing plant shall be transported in truck mixers, truck agitators, non-agitating trucks having special bodies or other approved containers.

IV-4-D-2-5-7 Time of Haul

The time elapsing from the time water is added to the mix until the concrete is deposited in place at the site of the work shall not exceed thirty (30) minutes when the concrete is hauled in non-agitating trucks, nor more than ninety (90) minutes when hauled in truck mixers or truck agitators.

IV-4-D-2-5-8 Delivery

The Contractor when supplying concrete from a central plant shall have sufficient plant capacity and transporting equipment to ensure continuous delivery at the rate required. The rate of delivery of concrete during concreting operations shall be such as to provide for the proper handling, placing and finishing of the concrete. The method of delivery and handling the concrete shall be such as will facilitate placing with a minimum of re-handling and without damage to the structure or the concrete. Methods of delivery and handling for each site shall be approved by the Engineer. The Engineer may delay or suspend the mixing and placing of concrete at any site for which he considers the Contractor's delivery equipment inadequate, until such time as the Contractor provides additional approved delivery equipment.

IV-4-D-2-5-9 Transporting

Concrete shall be transported to the place of final deposit by approved means.

Barrows, spades and other equipment used in the process of transporting concrete shall be thoroughly cleaned before each day's work or after a long interruption and they shall be free from hardened concrete.

Concrete shall be transported as soon as possible after mixing. by methods which will prevent the segregation, loss or contamination of the ingredients.

Bridging for traffic over reinforcement shall be provided so that the reinforcement is not distorted, damaged or displaced.

Where approval is obtained for concrete to be conveyed by chutes. these shall have a slope (not exceeding 1 vertical to ' horizontal) such as to ensure a continuous flow of concrete. Additional water shall not be introduced to assist the flow. If deposition is to be intermittent the chute shall be arranged to discharge into a storage hopper. In no case a clear fall of more than 1 m be permitted at the discharge end of the chute.

Where approval is obtained for pumping the concrete, the pump manufacturer's recommendations as approved by the Engineer shall be followed. The pumps used shall be of adequate capacity and power to ensure delivery of a continuous supply.

Wherever transport of concrete is interrupted for any period of over half an hour the chutes, pumps, pipes and any other means of distribution shall be thoroughly flushed out and cleaned. These shall also be flushed out immediately prior to resumption of concreting and shall be kept free from hardened concrete. All washing water used shall **be** discharged outside the formwork and clear of any freshly placed concrete.

IV-4-D-2-6 Handling, Placing, Concrete and Compacting

Concrete shall not be placed until forms and reinforcing steel have been checked and approved by the Engineer. The forms shall be clean and free of all debris before concrete is placed. The method and sequence of placing concrete shall be approved by the Engineer.

The external surface of all concrete shall be thoroughly worked during the placing by means of tools of an approved type. The working shall be such as to force all coarse aggregate from the surface and to bring mortar against the forms to produce a smooth finish, substantially free from water and air pockets, or honeycomb.

Concrete shall be placed so as to avoid segregation of the materials and the displacement of the reinforcement. Concrete shall not be deposited in large quantities at any point in the forms and then run or worked along the forms, thus causing segregation of the materials.

The concrete shall be deposited in the forms in horizontal layers and the work shall be carried on rapidly and continuously between predetermined planes agreed upon by the Contractor and the Engineer. Keyways shall be formed between layers.

Where steep slopes are required for placing concrete with chutes, the chutes shall be equipped with baffle boards or be in short lengths that reverse the direction of movement. Chutes and the use of chutes must be approved by the Engineer.

All chutes, troughs and pipes shall be kept clean and free from coatings of hardened concrete by thoroughly flushing with water after each run. The water used for flushing shall be discharged clear of the concrete already in place.

Concrete shall not be dropped in the forms a distance of more than one and one-half (1-1/2) meters, unless confined by approved closed chutes or pipes and care shall be taken to fill each part of the form by depositing the concrete as near final position as possible. The coarse aggregate shall be worked back from the forms and worked around the reinforcement without displacing the bars. After initial set of the concrete, the forms shall not be jarred and no strain shall be placed on the ends of projecting reinforcement.

Unless otherwise directed, the concrete shall be compacted with suitable mechanical vibrators operating within the concrete. When required, vibrating shall be supplemented by hand spading with suitable tools to assure proper and adequate compaction.

Vibrators shall be of an approved type and design.

Vibrators shall be so manipulated as to work the concrete thoroughly around the reinforcement and embedded fixtures and into corners and angles of the forms. Vibrators shall not be used as a means to cause concrete to flow or run into position in lieu of placing. The vibration at any point shall be of sufficient duration to accomplish compaction, but shall not be prolonged to the point where segregation occurs.

Concrete shall be deposited in water only with the permission of the Engineer and under his supervision. The minimum cement factor of the class of concrete being deposited in water shall be increased ten (10) percent without further compensation and the slump shall be approximately fifteen (15) centimeters. When depositing in water is allowed, the concrete shall be carefully placed in the space in which it is to remain in a compact mass, by means of a tremie, bottom-dumping bucket, or other approved method that does not permit the concrete to fall through the water without adequate protection. The concrete shall not be disturbed after being deposited. No concrete shall be placed in running water, and forms which are not reasonably watertight, shall not be used for holding concrete deposited under water.

Pumping will not be permitted from the inside of the foundation forms while concrete is being placed. If necessary to prevent flooding, a seal of concrete shall be placed through a closed chute or tremie and allowed to set.

When casings are used in drilled shafts, the casing shall be smooth and well-oiled and shall extend sufficiently above the grade of the finish shaft to provide excess concrete to be placed for the anticipated slump due to the casing removal. When the casing is to be pulled**,** the concrete placed in the casing shall have such a slump and be of such workability that a minimum amount of vibrating will be required.

No concrete work shall be stopped or temporarily discontinued within forty-five (45) centimeters of the top of any finished surface, unless such work is finished with a coping having a thickness less than forty-five (45) centimeters in which case the joint shall be made at the under edge of the coping.

Concrete in simple slab spans shall be placed in one (1) continuous operation for each span, unless otherwise indicated on the plans or approved by the Engineer. For continuous slab spans, concrete shall be placed in the sequence shown on the plans, except that with the approval of the Engineer, consecutive placement may be combined in a single placing operation to cover from one end of a unit to the other.

Concrete in simple or continuous T-beam spans may be placed in one (1) continuous operation, or when shown on the plans or approved by the Engineer, may be placed in two (2) separate operations; first, to the top of the girder stems, and second, to completion.

The concrete in arch rings shall be placed in such a manner as to load the centering uniformly.

Arch rings, preferably, shall be cast in transverse sections of such size that each section can be cast in a continuous operation. The arrangement of the sections and the sequence of placing shall be as approved by the Engineer, and shall be such as to avoid the creation of initial stress in the reinforcement. The sections shall be bonded together by suitable keys or dowels. When permitted by the Engineer, arch rings may be cast in a single continuous operation.

Before concrete floors are placed on steel spans, the centering under the spans shall be released and the spans swung free on their supports unless otherwise indicated on the plans. The operation of placing the concrete in any floor slab shall be continuous until complete, except where joints are provided on the plans or authorized by the Engineer. When a special sequence or method of concrete placing operations is indicated on the plans, or designated by the Engineer, this sequence or method shall be followed.

The method used for transporting concrete batches, materials, or equipment over previously placed floor slabs or floor units or over units of structures of continuous design types shall be subject to approval by the Engineer. Trucks, heavy equipment and heavy concentration of materials will be prohibited on floor slabs until the concrete has attained its design strength.

IV-4-D-2-7 Concreting in Deep Lifts

Where concrete is to be placed in lifts greater than 2.5 m high it shall be placed by suitable tremie pipes.

IV-4-D-2-8 Hot Weather Concreting (for temperatures above 20°C)

Concreting shall not be permitted if its temperature at placing is in excess of 38°C. In order to maintain the temperature of the concrete below this value the following precautions shall be taken wholly or in part as instructed by the Engineer:

All aggregate stockpiles, water lines and tanks as well as the mixer shall be protected from the direct rays of the sun.

Coarse aggregate shall be cooled by constant watering where possible.

Mixing water shall be cooled by the addition of ice to the storage tanks where necessary.

Rapid-hardening cement shall not be used.

Where the above precautions are inadequate concreting shall be carried out during the cooler parts of the day or during the night as may be directed by the Engineer.

When the air temperature is above 20°C loss of mixing water by evaporation shall be considered in arriving at the amount of water to be added to the mix. To maintain the water/cement ratio within permissible limits an approved water-reducing agent shall be included in the mix.

The maximum water/cement ratios may be increased with the Engineer's permission by 0.05 (or 2.5 litres/50 kg of cement) during mixing, but on no account shall water be added to concrete once it has left the mixer.

In order to reduce premature drying of the concrete during transporting and placing, all chutes, formwork and reinforcement shall be cooled by watering when possible, or shall otherwise be protected from the direct rays of the sun.

As soon as possible after concreting, the formwork shall be stripped and the surface of the concrete shall be treated.

Where drying winds are encountered, wind shields shall be positioned as necessary to protect exposed surfaces of the curing concrete.

IV-4-D-2-9 Wet Weather Concreting

Concreting during periods of constant rain shall not be permitted unless aggregate stockpiles, mixers and transporting equipment, and the areas to be concreted are adequately covered.

During showery weather, the Contractor shall ensure that work can be concluded at short notice by the provision of stop ends. On no account shall work be terminated before each section, between one stop end and another is complete. Adequate covering shall be provided to protect newly placed concrete from the rain.

IV-4-D-2-10 Cold Weather and Night Concreting

No concrete shall be mixed, placed or finished when the natural light is insufficient, unless an adequate and approved artificial lighting system is operated and such night work is approved by the Engineer.

Unless authorized in writing by the Engineer, mixing and concreting operations shall be discontinued when a descending air temperature in the shade and away from artificial heat reaches five (5) degrees C. When directed by the Engineer, the Contractor shall enclose the structure in such a way that the concrete and air within the enclosures can be kept above fifteen (15) degrees C for a period of seven (7) days after placing the concrete. The Contractor shall supply such heating apparatus as stoves, salamanders or steam equipment and the necessary fuel. When dry heat is used, means of maintaining atmospheric moisture shall be provided.

When directed by the Engineer, all aggregates or mixing water or both, shall be heated to a temperature of at least ten (10) degrees C, but nor more than twenty-one (21) degrees C the aggregates may be heated by steam or dry heat.

The temperature of the concrete shall be not less than fifteen (15) degrees C at the time of placing in the forms. In case of extremely low temperature, the Engineer may, at his discretion, raise the minimum limiting temperature for work, aggregates and mixed concrete. Salt, chemicals or other material shall not be used to prevent freezing.

IV-4-D-2-11 Joints

IV-4-D-2-11-1 Construction joints

Wherever the work of placing concrete is delayed until the concrete shall have taken its initial set, the point of stopping shall be deemed a construction joint. So far, the location of construction joints shall be as shown on the plans, but if not shown on the plans, they shall be planned in advance and the placing of concrete carried continuously from joint to joint. The joints shall be perpendicular to the principal lines of stress and in general be located at points of minimum shear.

Where dowels, reinforcing bars or other adequate ties are not required by the plans, keys shall be made by embedding water-soaked beveled timbers in soft concrete. The key shall be sized as shown on the details, or as directed by the Engineer, which shall be removed when the concrete has set. In resuming the Work the surface of the concrete previously placed shall be thoroughly cleaned of dirt, scum, laitance or other soft material with stiff wire brushes and if deemed necessary by the Engineer, shall be roughened with a steel tool. The surface shall then be thoroughly washed with clean water and painted with a thick coat of neat cement mortar, after which the concreting may proceed.

IV-4-D-2-11-2 Expansion joints

Expansion joints shall be constructed at the locations of the materials and to the dimensions shown on the plans.

A preformed expansion joint filler for concrete, bituminous type conforming to AASHTO M33 shall be placed in the joint. The joint filler shall cover the full depth minus the thickness required to place the bituminous putty at each joint. One face of the filler shall be held rigidly in place against the face of the concrete previously cast, while fresh concrete is placed against other face of the filler.

IV-4-D-2-11-3 Contraction joints

Contraction joints shall be constructed at the locations, of the materials and to the dimensions shown on the Plans.

IV-4-D-2-11-4 Cold Joints

When the continuous placement of concrete in any structural member is interrupted or delayed, for any reason, for a period long enough for the previously partially placed concrete to take its initial set, the Engineer shall declare such joint a cold joint and the Contractor shall immediately remove the previously partially placed concrete from the forms. No extra payment will be made for the initial placement or the removal of concrete which is wasted because of a cold joint. The Engineer may suspend all or any part of subsequent concrete Work until he deems the Contractor has corrected the cause of the cold joint occurrence.

IV-4-D-2-12 Holes, Cavities and Fixing

Holes shall be accurately marked and boxed-out for before concreting operations commence. No holes shall be formed after the concrete has set. Where bars, if placed to specified spacing would foul holes of size less than 250 mm x 250 mm. The full length of the bar shall be moved to one side unless otherwise indicated on the Drawings. For holes exceeding 250 mm x 950 mm, the bars shall be cut on site and lapped with additional equivalent bars.

Wherever possible, the Contractor shall build in all pipe work, Ironwork, and steelwork which passes through walls and floors. The pipe work, ironwork, and steelwork shall first be thoroughly cleaned and freed from any deleterious matter. Every care shall be taken to ensure that it is thoroughly encased in concrete.

Bolts, hooks and other fixings shall be embedded in concrete, or holes shall be drilled and fitted with threaded expanding anchors to receive the bolts. The Contractor shall ensure that bolts, hooks and fixings are accurately positioned Holding down bolts for machinery shall be set to template.

Where brick or stonework is to form a facing to the concrete or where the end of a brick or stone wall butts against a concrete face, galvanized metal ties of approved manufacture to BS 1243 shall be incorporated.

IV-4-D-2-13 Finishing

All top surfaces, such as the top of retaining walls, curbs, abutments, rails, etc., shall be treated by tamping and floating with a wooden float in such a manner as to flush the mortar to the surface and provide a uniform surface, free from pits or porous places. The surface thus obtained shall be troweled to produce a smooth surface and brushed lightly with a damp brush to remove the glazed surface.

Unless otherwise shown on the Drawings, all exposed concrete surfaces shall be fair faced and shall be free from honey-combing, fins, projections and air-holes. After removal of the forms, the Contractor, at his own expense, shall make good faulty surfaces by filling them with cement and sand (1/2 by vol.) mortar and rubbing them with a fine carborundum stone.

Immediately after the curing period, the Contractor shall repair all minor shrinkage cracks identified by the Engineer. Repairs shall be made as directed by the Engineer using an approved water resistant, high modulus low viscosity epoxy.

Unless otherwise provided on the plans, all true and even surfaces, obtained by use of a form lining, which are of a uniform color, free from stone pockets, honeycomb, excessive depressions or projections beyond the surface shall be considered as acceptable surfaces and a rubbed surface finish will not be required, except as follows:

The above provisions for surface finish shall not preclude requiring the use of a dry carborundum brick for straightening molding lines, removing fins, etc., or requiring a rubbed surface finish on all portions of the structure which do not present an acceptable surface even though a form lining is used.

Immediately after the curing period, the Contractor shall repair all minor shrinkage cracks identified by the Engineer. Repairs shall be made as directed by the Engineer using an approved water resistant, high modulus low viscosity epoxy.

IV-4-D-2-14 CURING AND PROTECTION

All concrete shall be cured for a period of time required to obtain the full specified strength, but not less than seven (7) consecutive days beginning immediately after placement. Curing shall be done according to one of the following pertaining methods:

IV-4-D-2-14-1 Water Curing

All surfaces, unless sealed by metal forms or submerged, shall be water cured including those surfaces which have previously had liquid curing membrane applied. For construction joints or other surfaces where no liquid membrane is specified, water curing shall begin within one (1) hour of placement. Where liquid membrane is placed, water curing shall begin within four (4) hours of placement.

For structure decks and slabs, the Contractor shall provide sufficient water and equipment to keep the surface of the concrete continually damp until the membrane curing is applied. The water shall be applied with a nozzle that so atomizes the flow that a mist and not a spray is formed. The moisture from the nozzle shall not be applied under pressure directly upon the concrete and shall not be allowed to accumulate on the concrete in a quantity sufficient to cause a flow or wash the surface.

Surfaces to be water cured shall be covered with wet sand, cotton mats, double thickness burlap or other equivalent absorbent material. The absorbent material shall cover the concrete surface completely. The material shall be completely saturated with water and kept continuously saturated throughout the curing period. After initial saturation, all surfaces shall be covered with polyethylene sheeting meeting requirements of ASTM C-171 or other approved impervious material. The sheeting shall be weighted or secured to prevent moisture loss. However, the surfaces of the concrete shall be readily available for inspection of the Engineer. The sheeting shall be in good repair. Sheeting that contains holes or is otherwise damaged shall be rejected by the Engineer. The Contractor shall be responsible for thoroughly inspecting and monitoring the concrete surfaces throughout the curing period. Additional water shall be added to any areas which are not still saturated. Inspections by the Contractor shall be conducted at least twice per day for the duration of the curing period and more often if ordered by the Engineer. The Engineer shall be advised of the inspection schedule and may accompany the workman to verify the acceptability of curing.

IV-4-D-2-14-2 Membrane Curing.

Except for construction joints and surfaces sealed by metal forms, liquid membrane shall be used as follows:

On wood formed vertical surfaces, forms shall be stripped as soon as practical and liquid curing membrane applied immediately except that those areas being rubbed or finished during the curing period shall be kept wet until finishing is complete when clear liquid curing membrane shall be uniformly applied.

On metal formed surfaces, with or without wood lining, liquid curing membrane shall be applied if the Contractor elects to strip the forms within the curing period.

The curing membrane used shall be in accordance with the requirements specified for curing membrane material, AASHTO M 148 Type 1-D. The curing membrane shall be applied in two (2) applications. The rate of each application of curing compound will be -as prescribed by the Engineer with a spreading rate per application of one (1) liter of liquid per five (5) square meters of concrete surface. If the concrete is dry or becomes dry, it shall be thoroughly wet with water and the curing compound applied just as the surface film of water disappears. During curing operations, any unsprayed surfaces shall be kept wet with water. Any curing membrane material on construction joints and/or reinforcing steel shall be completely removed before the following concrete pour.

Hand operated spraying equipment shall be capable of supplying a constant and uniform pressure to provide uniform and adequate distribution of the curing membrane at the rates required. The curing compound shall be thoroughly mixed at all times during usage.

No traffic of any kind will be permitted on the curing membrane until the curing period is completed, unless the Engineer permits the placement of concrete in adjacent sections in which case the damaged areas shall be immediately repaired as directed.

IV-4-D-2-14-3 Cold Weather-Curing

When concrete is being placed in cold weather, it shall be placed in accordance with the requirements provided in section "Cold weather and night concreting".

When concrete is being placed and the air temperature may be expected to drop below five (5) degrees C, during the curing period, the Contractor shall provide suitable measures such as straw, additional burlap, or other suitable blanketing materials and/or housing and artificial heat curing to maintain the concrete temperature between ten (10) degrees C and thirty-two (32) degrees C as measured on the surface of the concrete. The surface of the concrete shall be kept moist by the use of an approved moisture barrier such as wet burlap or polyethylene sheeting. The moisture barrier shall be maintained in intimate contact with the concrete during the entire curing period. After the completion of the required curing period, the Contractor shall remove the curing and protection in such a manner that rapid cooling of the concrete will be prevented.

When concrete is placed in cofferdams and subsequently flooded with ground water, the above curing conditions may be waived providing the surface of the water is not permitted to freeze.

IV-4-D-2-14-4 Steam Curing

Precast concrete members shall be cured for not less than seven (7) days by water or by steam curing, at the option of the Contractor. Steam curing for precast members shall conform to the following provisions:

After placement of the concrete, members shall be held for a minimum four (4) hours presteaming period. If the ambient air temperature is below ten (10) degrees Celsius, steam shall be applied during the presteaming period to hold the air surrounding the member at a temperature between ten (10) degrees and thirty-two (32) degrees Celsius.

To prevent moisture loss on exposed surfaces during the presteaming period, members shall be covered as soon as possible after casting or the exposed surfaces shall be kept wet by fog spray or wet blankets.

Enclosures for steam curing shall allow free circulation of steam about the member and shall be constructed to contain the live steam with a minimum moisture loss. The use of tarpaulins or similar flexible covers will be permitted, provided they are kept in good repair and secured in such a manner to prevent the loss of steam and moisture.

Steam at the jets shall be low pressure and in a saturated condition. Steam jets shall not impinge directly on the concrete, test cylinders, or forms. During application of the steam, the temperature rise within the enclosure shall not exceed five (5) degrees C per hour. The curing temperature throughout the enclosure shall not exceed sixty-five (65) degrees C and shall be maintained at a constant level for a sufficient time necessary to develop the required transfer strength. Control cylinders shall be covered to prevent moisture loss and shall be placed in a location where temperature is representative of the average temperature of the enclosure.

Temperature recording devices that will provide an accurate continuous permanent record of the curing temperature shall be provided. A minimum of one temperature recording device per sixty (60) meters of continuous bed length will be required for checking temperature.

Members in pretension beds shall be detensioned immediately after the termination of steam curing while the concrete and forms are still warm or the temperature under the enclosure shall be maintained over fifteen (15) degrees C until the stress is transferred to the concrete.

Curing of precast concrete will be considered complete after termination of the steam curing cycle.

All newly placed concrete for precast concrete piles, both conventionally reinforced and prestressed, shall be cured by steam as provided above except that piles with a designation of "Corrosion Resistant" shall be kept continuously wet for their entire length for a period of not less than seven (7) days including the holding and steam curing periods.

IV-4-D-2-14-5 Making Good

The cement mortar used in filling recesses in the concrete formed by hobbins in connection with formwork shall contain an approved expanding admixture.

IV-4-E PRECAST CONCRETE

IV-4-E-1 Precast Concrete

This section includes the work for furnishing and installing precast concrete canal or miscellaneous structures as shown on plans. Reinforcement shall be in accordance with detail shown on plans.

Precast concrete units shall be manufactured of 250 kg/cm² compressive strength air-entrained concrete. The maximum size of aggregate shall be 1.9 cm. The minimum cement content shall be 350 kilograms of cement per cubic meter of concrete. The final finish surface shall be smooth with the Manning-Strickler coefficient (k_s) not less than 60. Precast units shall be true to line, plane and dimensions in accordance with the following special requirements :

IV-4-E-1-1 Plant Requirements

The units shall be manufactured in an approved area or enclosed building under the Engineer's control and inspection with guaranteed provision to meet the requirements for curing and protecting the concrete as specified.

IV-4-E-1-2 Forms

Metal of tight rigid construction, true to shape, and with smooth finish shall be used.

The forms shall be oiled in any approved manner. Re-use of old, worn, or misshapen forms, will not be allowed.

IV-4-E-1-3 Vibration

Vibrators shall be provided and used as directed by the Engineer. Prolonged vibration shall be avoided in order to prevent surface finish susceptible to crazing. Units showing surface checking or crazing will be rejected.

IV-4-E-1-4 Protection And Curing

The units shall be cured either by steam or water for a sufficient length of time for the concrete to obtain the minimum compressive strength.

IV-4-E-1-4-1 Steam Curing

Two to four hours after the concrete has been placed and attained the initial set, the first application of steam shall be made. Forms shall be removed after the units have been steam cured for 24 hours.

The steam shall be at 100% relative humidity to provide moisture for proper hydration of cement. The steam shall be directly applied onto the concrete. During application of steam the ambient temperature shall increase at the rate not to exceed 4.4° C per hour until a minimum temperature of 54° C is reached.

When discontinuing the steam application, the ambient temperature shall be decreased at the rate of 4.4° C per hour until a temperature of -6.7° C above the atmospheric temperature has been attained. The concrete shall not be exposed to temperature below freezing for a minimum of 6 days after casting.

IV-4-E-1-4-2 Water Curing

The units may be water cured with water, saturated material or other acceptable or approved methods that will keep the units moist for a period of 5 days. Under no condition will the use of curing compounds be permitted.

Concrete delivered in outside temperature lower than 4.4° C shall arrive at work having a temperature not less than 15.6° C nor greater than 32.2° C. Water and aggregates shall be heated if necessary but the water shall not be heated above 60° C. The use of direct heating torch in mixer shall not be approved.

IV-4-E-1-4-2-1 Testing and Sampling

Representative test specimens of the concrete shall be taken by the Engineer. No precast units will be shipped to the project until the test specimen cured show a compressive strength of 250 kg/cm².

IV-4-E-1-4-2-2 Inspection

All precast units shall be subject to inspection at the point of manufacture and any units showing defects or damage before the completion of the project shall be removed and replaced at the expense of the Contractor.

IV-4-F SAMPLING & TESTING

IV-4-F-1 General Requirements

IV-4-F-1-1 Sampling & Testing

All concrete, aggregate, cement and water shall be sampled and tested during construction as frequently as deemed necessary by the Engineer. All test samples shall be supplied by the Contractor at his expense. Samples shall be obtained in accordance with AASHTO T 23, T 141, T 2, T 127 and T 26. All costs connected with manufacturer's Certificates of Guarantee, laboratory analysis and all subsequent testing for material acceptance shall be borne by the Contractor

The Contractor shall provide on the Site equipment, staff and labor for carrying out the sampling and testing and he shall carry out any or all of these tests at such times and with such frequency as may be requested by the Engineer.

All equipment shall be calibrated and checked from time to time as the Engineer may require.

The Contractor shall provide all samples required by the Engineer. Those samples to be tested in an off site laboratory shall be carefully forwarded by the Contractor to an approved laboratory. Results of laboratory and site tests shall be kept on site and copies of all test reports shall be forwarded in duplicate to the Engineer.

Frequency of tests and the number of samples required will be governed by the results of the previous tests the quality of the materials revealed during the tests and the uniformity of that quality. Should it become evident that the quality of concrete is deteriorating the Engineer may require additional samples to be taken and test cubes to be made and tested to determine the cause.

IV-4-F-1-2 Quality Control

Compliance with the specified characteristic strength shall be based on tests on cubes at an age of 28 days. Sampling and testing of concrete shall comply with BS 1881. For major structures the frequency of sampling shall be initially three samples taken each day for five days of concreting and thereafter at a frequency of one sample per 10m³ of concrete but not less than one sample for each day concreting.

For minor structures the frequency of sampling shall be one sample per 20 m³ but not less than one sample for each day concreting. For mass concrete works and concrete works at pipeline appurtenances sampling shall be at on average of one sample per 50 m³.

A minimum of 3 test cubes shall be made from each sample.

Where materials are of an unfamiliar grading or type, or where directed by the Engineer compression tests shall be carried out at 7 days and adjustments made in advance of the main control methods outlined above.

Cube test results will be examined individually in 10 consecutive sets of four and the standard deviation and mean strength of each set calculated. The concrete mix proportions will only be acceptable if all of the following requirements are complied with :

Not more than two results in 40 are less than the characteristic crushing strength.

TABLE 5.3 MASS OF DRY AGGREGATE TO BE USED WITH 100 KG OF CEMENT

Grade of concrete	**Nominal maximum size of aggregate (mm)**	**40**		**20**		**14**		**10**	
	Workability	Medium	High	Medium	High	Medium	High	Medium	High
	Range for standard sample (mm)	50-100	80-170	25-75	65-135	5-55	50-100	0-45	15-65
	Range for sample taken in accordance with 9.2 (mm)	40-110	70-180	15-85	55-145	0-65	40-110	0-55	5-75
		kg	kg	kg	kg	kg	kg	kg	kg
C7.5P		1080	920	900	780	N/A	N/A	N/A	N/A
C10P		900	800	770	690	N/A	N/A	N/A	N/A
C15P	Total	790	690	680	580	N/A	N/A	N/A	N/A
C20P	Aggregate	660	600	600	530	560	470	510	420
C25P		560	510	510	460	490	410	450	370
C30P		510	460	460	400	410	360	380	320

N/A - not applicable

TABLE 5.4 PERCENTAGE BY MASS OF FINE AGGREGATE TO TOTAL AGGREGATE

Grade of concrete	**Nominal maximum size of aggregate (mm)**	**40**		**20**		**14**		**10**	
	Workability	Medium	High	Medium	High	Medium	High	Medium	High
C7.5P } C10 P } C15P }		30-45		35-50		N/A		N/A	
	Grading zone 1	35	40	40	45	45	50	50	55
C20P } }	2	30	35	35	40	40	45	45	50
C25P } }	3	30	30	30	35	35	40	40	45
C30P } }	4	25	25	25	30	30	35	35	40

N/A = not applicable

Notes on the use of Tables 5.3 and 5.4

NOTE 1. The proportions given in the tables will normally provide concrete of the strength in N/mm² indicated by the grade except where poor control is allied with the use of poor materials.

NOTE 2. For grades C7.5P, C10P and C15P a range of fine-aggregate percentages is given, the lower percentage is applicable to finer materials such as zone 4 sand and the higher percentage to coarser materials such as zone 1 sand.

NOTE 3. For all grades, small adjustments in the percentage of fine aggregate may be required depending on the properties of the particular aggregates being used.

NOTE 4. For grades C20P, C25P and C30P and where high workability is required, it is advisable to check that the percentage of fine aggregate stated will produce satisfactory concrete if the grading of the fine aggregate approaches the coarser limits of zone 1 or the finer limits of zone 4.

No value of the average for any set of four results is less than the characteristic strength plus one-half of the design margin.

When 40 results have been obtained and the mean strength and standard deviation are calculated, the mean strength minus 1.64 times the standard deviation shall be greater than the characteristic strength.

Where the results do not conform to the above requirements the following action shall be taken :

Adjustments to the mix shall be made to obtain the strength required.

In the case where any result is less than 80° of the characteristic strength, the structural implications shall be considered and action taken as ordered by the Engineer.

For those Prescribed Mixes required to be tested, requirements (i) and (ii) only still be applicable.

IV-4-F-1-3 Concrete Compression Tests

The Engineer will make and cure the cylinders from concrete as mixed for the work, which will be tested in accordance with AASHTO T 22 after seven (7) and twenty-eight (28) days. Test specimens shall be made and cured in accordance with AASHTO T 23. These specimens will be the basis for acceptance of the concrete in the structure.

They also provide means for checking the adequacy for laboratory mixture proportions for strength. If the average of the strength tests of the specimens falls below the minimum allowable compressive strength at seven (7) or twenty-eight (28) days, the concrete mix shall be redesigned. In the determination of the average compressive strength of the specimens, no cylinder specimen shall have a strength less than eighty-five (85) percent of the allowable strength.

The Engineer will take a total of four (4) cylinders from each day's run of concrete at each structure site. Two (2) cylinders will be for the seven (7) day test and two (2) cylinders for the twenty-eight (28) day test. All four (4) specimens are to be taken from the same batch. The Contractor shall give the Engineer full cooperation and, when requested by the Engineer, labor assistance in preparing the cylinders. When directed by the Engineer, the Contractor shall transport the cylinders from the structure site to the laboratory.

The Engineer may make additional test cylinders to ascertain the effectiveness of the methods by which the structure is being cured and also to determine when the structure may be placed in service. These cylinders shall be cured in the field in the same manner as the concrete placed in the structure, and the Contractor shall protect the cylinders from all damage.

The Contractor shall take every precaution to prevent injury to the test cylinders during handling, transporting and storing. He will be held solely responsible for any test failures caused by improper handling and transportation, or any other cause which may be detrimental to the test cylinder.

In order that the test cylinders may be transported from field to laboratory undamaged, the Contractor shall provide a minimum of two (2) approved metal boxes. [One (1) for the Contractor's use and one

(1) for the Engineer's use.] Boxes shall be of such size to receive a minimum of six *(6)* test cylinders and leave space for sawdust packing around all surfaces of the cylinders. Boxes shall be approved by the Engineer. The Contractor shall, when directed by the Engineer, provide as many additional boxes as may be required by the remoteness and/or magnitude of the concrete work.

When test cylinders fail to meet minimum strength requirements, the Engineer may require core samples to be taken to determine the acceptability of such structures. the contractor shall, at his own expense, furnish all equipment required for such core samples.

IV-4-F-1-4 Loading Tests

The Engineer may permit that a loading test be made on the works or any part thereof for one or more of the following reasons :

Failure of "Site Cubes" to attain the strength requirements.

Premature removal of formwork.

Overloading of structure during construction.

Improper compaction and/or curing of concrete.

Any other circumstances attributable to alleged negligence on the part of the Contractor, which, in the opinion of the Engineer, may result in a structure being of less than the required strength.

Loading test shall be carried out in accordance with the requirements of BS 8110.

If the results of the test are not satisfactory, the Engineer will direct that the part of the work concerned be taken down or removed and reconstructed to comply with the Specification, or that such other remedial measures as he may think fit be taken to make the work acceptable.

The Engineer may instruct the Contractor to take out cylindrical core specimens from the structures concerned and have them tested. The cutting equipment and the method of doing the work shall be to the Engineer's approval. The specimens shall be dealt with in accordance with BS 1881. Prior to testing, the specimens shall be available for examination by the Engineer.

IV-4-G WATER RETAINING STRUCTURES-SPECIAL CLAUSES

The design, detailing materials and workmanship shall comply with the requirements of BS 8007.

IV-4-G-1 Making Good

The cement mortar used in filling recesses in the concrete formed by bobbins in connection with formwork shall contain an approved expanding admixture.

IV-4-G-2 Construction Joints in Water Retaining Structures

Waterstop not less than 150 mm Bide shall be built into all construction joints in external walls and construction. Construction joints shall only be formed at positions approved by the Engineer.

IV-4-G-3 Watertightness of Structures

The Contractor shall be responsible for the watertightness of structures and any remedial measures necessary. Where detailed on the Drawings the surfaces of concrete shall be coated with a waterproof coating.

In the event that a structure designed and specified to be water retaining fails to satisfy the watertightness tests, the Contractor shall undertake such remedial works as are necessary and are approved by the Engineer. In certain situations the Engineer may permit the provision of an internal waterproofing coating in compliance with the specification. Where such a coating is permitted it shall be applied to the whole of the internal water retaining face.

IV-4-G-4 Waterproof Coatings

Waterproof coatings shall be applied only where shown in the drawings or where instructed by the Engineer.

Coating shall comprise a thin layer render system which is chloride free and suitable for contact with potable water.

The system shall be applied in accordance with the manufacturer's recommendations. Prior to application, the surfaces shall be prepared and all cracks, porous patches and generally defective areas shall be cut-out and made good.

The system shall provide a waterproof coating without impeding the breathing of the structure.

Expansion joints shall be formed in the waterproofing system by the use of compatible sealants as recommended by the manufacturer.

The system shall be cured for a period of not less than 7 days.

IV-4-G-5 Hydrophillic Rubber Sealer

Hydrophillic rubber sealer shall be co-extruded from chloroprene and hydrophillic rubbers into a cellular strip approximately 25 mm x 7 mm thick which expands as it absorbs water. The strip shall incorporate an expansion delay coating to prevent activation during setting of the surrounding concrete.

Hydrophillic rubber sealer shall be applied to the perimeter of all pipes to be built into concrete structures to existing concrete walls and slabs at or below water levels which have been demolished and require extension, and to other locations as indicated on the Drawings.

The strip sealer shall be bonded to the pipe diameter or on to the face of demolished structures on to which new concrete is to be placed so as to be at least l00 mm from the wall surface. Where dowel bars are incorporated in bonding new concrete to old, the sealer shall be placed above the dowel bars on the "wet" side of the structure. Bonding shall be accomplished using proprietary neoprene or epoxy adhesives to ensure the sealer is not disturbed during placement of the concrete.

The application shall be in accordance with the manufacturer's recommendations.

IV-4-G-6 Protective Bituminous Coating for Buried Surfaces

IV-4-G-6-1 General

The Bituminous Coating intended for concrete protection shall be supplied with manufactures' certificate, stating that the product have been factory tested in accordance with specifications and standards, (i.e. ISO, BS, AFNOR, etc …), and full technical data.

IV-4-G-6-2 Description

Solvent-Base Bituminous Coating shall be used for providing permanent protection for concrete surfaces indirect contact with soil or buried structures.

IV-4-G-7 Application

All surfaces of concrete ready for the application of the bituminous coating shall be clean, free from grease, oil, standing water, and all loose adhering particles. The protective coating can be applied either by brush, roller, or airless spray gun. Allow the minimum required period recommended by the manufacture between coats.

IV-4-H DEMOLITION & REMOVAL

IV-4-H-1 Description

This work shall consist of the complete demolition and removal of a whole, not partial, structural concrete and miscellaneous concrete structures as indicated on the plans or as ordered by the Engineer. All demolition material shall be removed from the work site to approved dumping site.

IV-4-H-2 Demolition Details

Care shall be exercised in the demolition so as not to damage neighboring structures designated to remain in place.

IV-4-H-3 Structural Concrete Removal

IV-4-H-3-1 Description

This work shall consist of the removal of a section or segment from a structural concrete elements and other concrete removal indicated on the Plans or ordered by the Engineer. All removed material shall be removed from the work site to approved dumping sites.

IV-4-H-3-1-1 Removal of structural concrete

All concrete shall be removed to a pay line shown on the Plans or to sound surface as determined by the Engineer. Reinforcing bars and miscellaneous material shall be removed as part of this work unless the Plans or the Engineer specifically direct otherwise. Surfaces from which structural concrete has been removed shall be cleaned, except that surfaces not designated to come in contact with new concrete placements need not be cleaned.

Chipping hammers shall weigh no more than 20 kg with the bit and muffler removed. The hammer shall deliver no more than 1600 blows per minute. The Contractor shall provide the Engineer information from the hammer manufacturer that these requirements are not exceeded. The air pressure used to power the hammer shall not exceed 759 KPa measured at the air compressor. An air pressure gauge in proper working condition shall be provided. Only sharp chisel point bits shall be used. All bits determined by the Engineer to be dull shall be sharpened or replaced. If the Engineer determines that the Contractor's operations are resulting in damage to concrete that is to remain, the Contractor shall make immediate corrections. These corrections shall include the use of a lighter chipping hammer if so ordered by the Engineer.

IV-4-H-3-1-2 Materials

Materials used in this work shall conform to the following requirements :

Sandblasting Sand : No. 40 Boiler Slag Grit or No. 2 Sandblast Sand

IV-4-H-3-1-3 Construction Details

General care shall be exercised in removing concrete so as not to damage material designated to remain in place. Reinforcement designated to remain in place shall be cleaned in a manner satisfactory to the Engineer. Saw cutting of concrete shall be performed only where indicated on the Plans or where ordered by the Engineer.

All concrete surfaces which require cleaning, after the concrete removal has been performed, shall be thoroughly sandblast cleaned, or abraded by other mechanical means satisfactory to the Engineer. After blast cleaning, the surface shall be air blown or vacuum cleaned. Air-blowing may be used on vertical or overhead surfaces. Vacuum cleaning will be required for all other surfaces.

For any structural concrete removal item, where a hammer size limitation is specified on the Plans or in the Specifications, the Engineer may order the Contractor to use a lighter hammer than that specified, if, in his opinion, the hammer being used is destroying concrete that should remain.

IV-4-I CONCRETE GROUTING MATERIAL

IV-4-I-1 Scope

This specification covers a grouting material for use in grouting anchor bolts, dowels and other miscellaneous items in concrete.

IV-4-I-2 General

The material shall be a non-metallic, non-shrink grout which, when mixed with water, will harden rapidly to produce a permanent anchoring bond. It shall contain no metals nor rust or corrosion promoting agents. The color shall be light gray matching approximately the color of hardened concrete.

IV-4-I-3 Material Requirements

The material when prepared in accordance with the manufacturers instructions, shall be of a trowelable consistency. It shall also have the following properties :

The material shall exhibit no shrinkage on setting but may exhibit slight expansion of no more than 0.40%.

Compressive strength - Two-inch cubes of this material when cured as shown shall have the following minimum compressive strengths :

Cure	Strength
24 hour air cure @ 23° C	27.6 MPa/Min.
7 day air cure @ 23° C	41.4 MPa/Min.
7 day air, 10 day water submersion	41.4 MPa/Min.
7 day air, 24 hour, 10% NaCl solution submersion, 25 cycles freeze-thaw	41.4 MPa/Min.

The material shall have a minimum initial set of 30 minutes.

Pull-out strength - T15 concrete reinforcement bar grouted 15 cm deep in 2.2 cm hole in saturated surface dried concrete shall have a pull-out strength of 4500 kg.

The material shall contain not more than 0.05% chlorides or 5% sulfates. The material shall withstand 25 cycles of freeze-thaw (10% NaCl) with a maximum loss of 4%.

IV-4-J CONCRETE REPAIR WORKS

IV-4-J-1 Description

This work shall consist of rehabilitation works for canals, gravel traps, sluice gates operating chambers, stilling basins, distributors, chutes, aqueducts and other specified works.

IV-4-J-2 Epoxy Mortar

IV-4-J-2-1 Description

Epoxy mortar is a blend of high strength aggregates bonded together with epoxy resin, designed for speedy and permanent repairs, to concrete. The mortar shall provide shrinkage-free hardening and abrasion and impact-resistance. The mixed material is applied to a suitably prepared and primed surface. It is supplied as a three pack material in pre-weighed quantities ready for on site mixing and use.

IV-4-J-2-2 Preparation Of Concrete Surface

The surface to be prepared will be sandblasted after which it will be thoroughly cleaned and dried prior to epoxy bonding coarse.

All grease, chemical contamination, dust, cement, laitance, and loose concrete must be removed by scrabbling or light bush hammering to provide a sound substratum.

IV-4-J-2-3 Priming Surfaces

Surfaces to be repaired shall be primed with an epoxy primer. The epoxy mortar shall be applied when the primer starts to gel but is still tacky, normally between 30 minutes and one hour. If the concrete has absorbed the primer, or the primer has dried, a second primer coat should be applied.

IV-4-J-2-4 Technical Properties

The contractor shall submit catalogues from manufacturers for approval of the Engineer. It shall conform to the following properties:

	NORMAL TYPE	L.P. TYPE
Compressive strength	70-80N/mm^2	50-60N/mm^2
Flexural Strength	20-25N/mm^2	15-20N/mm^2
Bond Strength to concrete	2-3N/ mm^2	2-3N/mm^2
Young's Modulus	27.000N/mm^2	27.000N/mm^2
Mixing Ratio	1 part epoxy to 3 parts silica sand	

where : Normal type : Have storage conditions above 0°C, max. 25°C.

L.P. type : Have storage conditions above 10°C, max. 35°C.

II.4.K.2.5 Application

The mixed material should be applied to the surface with a steel trowel, ensuring that it is pressed firmly into cracks to ensure positive adhesion. Epoxy coatings shall be kept dry and above 16°C.

IV-4-J-2-5 Safety

For health and safety, the instruction of the epoxy manufacturer should be followed.

IV-4-J-3 Epoxy Resin Bonding Agent

IV-4-J-3-1 Description

Epoxy resin bonding agent is a solvent-free bonding agent, based on selected epoxy resins. After application to old concrete surfaces, it shall provide a perfect bond for new concrete. It is supplied as a two component bonding agent ready for mixing with a slow speed electric drill.

IV-4-J-3-2 Preparation of Concrete Surface

All surfaces must be clean, free from standing water and all loosely adhering particles. Cement laitance must be removed and the surfaces to be treated must be roughened.

IV-4-J-3-3 Technical Properties

The contractor shall submit catalogues from manufacturers for approval of the Engineer. It shall conform to the following properties :

Compressive Strength	60-70N/mm^2
Flexural Strength	30-35N/mm^2
Tensile Strength	8-20N/mm^2
Bond Strength to Concrete	2.5-3N/mm^2 (concrete failure)

IV-4-J-3-4 Application

The mixed material should be applied to the surface by brush, roller or spray, ensuring that it is well brushed in on damp surfaces. New concrete should be poured within specified time when the material is still tacky.

IV-4-J-3-5 Safety

For health and safety, the instruction of the epoxy manufacturer should be followed.

PART IV – CIVIL WORKS

5. Rehabilitation of Existing Structures

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IV-5-A GENERAL REQUIREMENTS

IV-5-A-1 General

The following specifications include procedures, materials and workmanship for the rehabilitation of existing structures.

Rehabilitation works will include, but will not be limited to structural repairs and general building rehabilitation.

Structural Repairs will include:

- Repairs to cracked concrete.
- Sealing joints and cracks to prevent leakage.
- Sealing of pipe penetrations including replacement of some pipes.
- Repairs to spalled concrete.
- Repairs and replacement of corroded reinforcement.
- Removal and replacement of plaster and rendering.
- Major structural demolition and reconstruction.
- Internal and external tanking and waterproofing.
- Earthworks.
- Replacement of miscellaneous metalwork, access ladder covers and the like.

The procedure for the rehabilitation of ilding structures shall be for the Contractor to first undertake an initial Site Survey. This survey will determine the general nature and condition of the site, the structure, pipework, ancillaries and electrical Plant. Based upon the results of this survey, the Engineer together with the Contractor shall plan and undertake a detailed structural inspection/survey. This detailed survey will identify the extent and nature of any defects which in the opinion of the Engineer needs to be rehabilitated or repaired. The Engineer will instruct the Contractor as to the extent and method of rehabilitation or repair to be implemented. In the case of major defects, the Engineer may instruct the demolition and reconstruction of the structure either in whole or in part.

Only structural repairs are defined beneath for reservoirs and pumping station buildings.

IV-5-A-2 Site Survey

The Contractor shall record the existing state of the site, the structure and its associated plant and equipment and shall produce dimensioned drawings of the structure comprising plans and sections at a scale of not less than 1:100 and dimensioned plans and layouts of any existing mechanical and electrical plant and ancillaries.

The drawings and condition survey shall be supported by photographs and shall be submitted to the Engineer for approval within 10 days of the survey.

IV-5-A-3 Structural Survey

The Engineer together with the Contractor's engineer accompanied by adequate support staff shall inspect the structure to assess its condition and determine the scope of the rehabilitation work. The survey shall include a cover meter survey and rebound hammer survey of concrete surfaces.

Structural surveys may need to be undertaken in stages involving a number of visits by the Engineer and Contractor. The scope of work may be amended by the Engineer, as necessary, to incorporate the findings of the surveys.

To facilitate the structural surveys it may be necessary to remove existing plastering and rendering, clean the structure, excavate to expose buried surfaces, provide temporary accesses and scaffolding, carry out water tightness testing or other preparatory work. The preparatory work to be undertaken will be instructed by the Engineer after receipt from the site survey. Further instructions may be issued by the Engineer during the course of the detailed survey and the rehabilitation works.

IV-5-A-3-1 Cover Meter Survey

Cover meter surveys shall be carried out using normal methods and equipment. On plane members the direction of reinforcement with least cover shall be determined. The cover meter head shall he moved across the surface of the concrete along a line in a direction perpendicular to the direction of reinforcement with least cover and with the head oriented in the direction which enables the cover to that reinforcement to be measured. The lines along which the cover meter head is moved shall be approximately 500 mm apart.

IV-5-A-3-2 Rebound Hammer Survey

Rebound hammer for testing the hardness of concrete shall be carried out in accordance with International codes and standards as instructed by the Engineer.

IV-5-A-4 Access

The contractor shall provide suitable and safe means of gaining access to all repair areas to enable the works to be carried out and the Engineer to carry out surveys inspections.

IV-5-B CONTRACTOR'S METHOD STATEMENT

Prior to commencing rehabilitation the contractor shall submit for approval a detailed method statement which shall include.

- A program detailing the proposed sequence and duration of each item of work.
- Details of any necessary disruption to the operation of the works and the contractor's proposed methods of providing any temporary service.
- Details of all detailed method statements.
- Details of all materials to be used in the rehabilitation works together with all necessary technical documents, catalogues and samples.
- Descriptions of any items including pipework, mechanical and electrical plant and miscellaneous work related to rehabilitation including proposed schedule of design, procurement and delivery.

IV-5-C CONCRETE REMOVAL

IV-5-C-1 General

Where existing concrete is to cut out it shall be removed over the areas defined by the Engineer. The contractor shall ensure that the cutting out is done in such a manner so as not to cause permanent damage to the surrounding structure.

Where practicable, concrete shall be removed by disc cutting, grinding or similar cutting methods and not by percussive tools.

Where percussive methods are approved by the Engineer, the size and power of tool shall be the minimum appropriate.

Before removing any concrete the Contractor shall provide and erect any temporary propping necessary to ensure the safety of the structure.

The Contractor shall be liable for making good of his own expense any damage arising from cutting out.

Where concrete is to be removed the surface of the concrete over the area to be removed, shall be cut by a grid of straight lines using a disc cutter or similar and the concrete removed by chiseling or by percussive tools.

IV-5-C-2 Removal of Unsound Concrete

1. Removal for concrete replacement ; The minimum depth of removal shall be the greater of the following :

   a. A depth no less than 1cm and not greater than the distance from the rearmost point of exposed reinforcement to sound concrete.

   b. The depth necessary to reach sound concrete.

   Should the removal depth exceeds 15 cm, the Project manager may order supplementary anchoring as part of the replacement procedure. The sides of the cavity shall be made at a slight angle, so that the width of the base of the cavity is greater than the opening at the surface, thereby providing a key.

2. Removal for patching material replacement: Feather edges shall not be permitted. The minimum patch depth shall be 1 cm as measured from the theoretical plane of the original concrete surface.

IV-5-C-3 Corroding Reinforcement

Where the reinforcement bars are corroded, concrete shall be removed to a depth of 25mm behind and along the actively corroding bars until a continuous length of 50 mm of bar which is free from active corrosion is exposed.

The Contractor may be directed by the Engineer to supplement or replace the existing bars with new bars. Bars to be replaced shall be cut out and not removed by burning.

Replacement reinforcement shall be adequately fixed and tied in position such that it will not be displaced during the subsequent reinstatement works.

Where corroding reinforcing bars are to be retained they shall be brushed and cleaned by grit blasting or other method approved by the Engineer and submitted by the Contractor. Cleaning shall be carried out in such a way to include the hidden faces at the backs of bars and at the intersection of bars. Abrasives shall be new, clean and dry and of a grade suitable for the preparation of steel to the qualification required above. The exposed reinforcement shall be thoroughly washed down with clean water.

IV-5-C-4 Surface Cleaning

Cleaning of structures shall be undertaken to remove all dirt or other contaminants, previous coatings, paint, moss, plant growth and the like, as directed by the Engineer. Cleaning shall be by methods that cause no damage to the existing structure. The Engineer may instruct a change in the method if the method adopted causes damage to the surface or is otherwise unsuitable or ineffective.

Where instructed by the Engineer cleaning shall be by:

- Grit blasting (wet, dry or vacuum blasting).
- High pressure water jetting, steam cleaning employing wax free detergents together with power scrubbing as necessary.

Before cleaning begins, the contractor shall remove all surface attachments from the areas to be cleaned or from positions that obstruct access. Unless otherwise directed. all inserts and fixings which have been cast in or mortared into pockets or otherwise attached to the concrete shall be protected or removed from the area to be cleaned.

Before cleaning commences, trials shall be carried out on areas at typical locations to the approval of the Engineer.

IV-5-C-5 Reinforcement Protective Treatment

Where directed by the Engineer reinforcement shall be coated with a polymer modified cement based primer or slurry coat prior to reinstatement of the concrete. All exposed surfaces of the bars shall be coated with the primer within 3 hours of cleaning. Any reinforcement remaining uncoated at the end of a 3 hours period shall be recleaned.

IV-5-D CONCRETE REPAIR METHODS

Defective concrete shall be cut out and reinstated by either a proprietary repair method or in the case of large volumes, by recasting with new concrete. Any defective or corroded reinforcement will either be cleaned and protected by a corrosion protection system or replaced.

Concrete repair methods shall include, but shall not be limited to, the following:

- Hand application of resin based mortars
- Hand application of cementitious mortars.
- Sprayed concrete and mortar
- Recasting with concrete

The Contractor will determine and submit to the Engineer the extent of the concrete to be removed and will select the appropriate repair method and material of repair depending upon the nature and extent of the defect. Repair methods and materials of repair shall be submitted to the Engineer’s approval.

In general hand applied resin based mortars and cementitious mortars will be used for patch repairs to areas of less then 0.5 m² and depths less then 100 mm. Re-casting into formwork will be used for the reinstatement of large volumes and sprayed concrete (Gunite) will be used to cover large areas.

IV-5-E REINSTATEMENT OF CONCRETE

IV-5-E-1 General

Prior to placing repair materials in any section of the works, all profile guides, formwork and reinforcement shall be fully fixed and cleaned over the entire area of the proposed repair. All dust, debris and loose material shall be removed from the area of the repair.

Plant and tools used for mixing, transportation and spraying of repair materials shall be kept clean and free from accumulated deposits of repair material.

Repair materials shall be mixed and applied in accordance with the manufacturer' s recommendations as approved by the Engineer. The entire contents of a pack (or any other type of container) shall be mixed at one time.

Transportation of the repair materials to the point of application shall be such as to prevent contamination, segregation or loss of fine constituent materials.

Repair materials shall be placed in position in as short time as possible after mixing and within times stated in the manufacturer's recommendations. The repair material shall be placed in layers not exceeding those recommended by the manufacturer and approved by the Engineer.

Repairs shall not proceed if the air temperature or concrete substrate temperature is 5°C or less, or such higher temperature as may be recommended by the manufacturer and shall cease if the air temperatures falls below this minimum.

Repair may proceed at low temperatures if specific planned and approved procedures are implemented. These may include:

- Provision of heated tenting which envelopes the repair area and produces an environment with a sustainable air temperature in excess of the minimum.
- Where approved by the manufacturer warming materials and the substrate to a temperature above 5°C. The method of warming shall be such that the materials are not damaged and are not caused to dry out in the case of cement based repair materials.
- Insulating the completed or partially completed repairs in accordance with good practice for winter concreting.

The Contractor's determinations shall be made in accordance with the criteria of this subsection, and only in the absence of directions from the plans, or the Engineer.

1. Horizontal or essentially horizontal locations: Concrete or approved patching material shall be used. Class A concrete shall be placed only at locations where removal depths average out greater than 8 cm. Patching material shall be placed only at locations where removal depths average out less than 8 cm. Average depths shall be determined by a measurement procedure acceptable to the Engineer.
2. Vertical or essentially vertical locations. Concrete, or approved patching material shall be used. Concrete shall be restricted to the depth limitations noted for horizontal locations. Average depths shall be determined by a measurement procedure acceptable to the Project manager.
3. Overhead. Approved patching material shall be used. Lift thicknesses shall not exceed 2 cm, unless formwork or anchoring devices are employed.

IV-5-E-2 Materials

Where the repair system comprises two or more materials the Contractor shall ensure that the repair materials are compatible and shall submit to the Engineer certificates provided by the manufacture confirming that the proposed repair materials are compatible.

Where possible repair materials, other than replacement concrete, shall be pre-batched.

All materials shall be mixed, applied and cured in accordance with the manufacturer's recommendations as approved by the Engineer or as otherwise instructed by the Engineer.

IV-5-E-3 Formwork

Formwork necessary to reform arises, profiles, rebates, soffits, and the like shall be so constructed that it remains true to line and level under the loads and pressure imposed by the repair materials.

Formwork shall be struck without causing damage to the repair materials, and the contractor shall be responsible for determining the age at which the repair material attains a sufficient strength to support its self weight and any other loads which may be imposed thereon.

All profiled guides and formwork shall be coated and/or adequately treated such that they do not absorb water from the repair mortar and do not discolor/contaminate the repair mortar or surrounding concrete.

IV-5-E-4 Resin Based Mortars

Resin based mortars shall be two or three pack epoxy resin system incorporating a suitable filler to produce a thixotropic mortar. Lightweight fillers may be used to produce a low density mortar for use on vertical and overhead applications.

The mortar shall be solvent free and shall exhibit the following minimum properties:

Compressive strength	50 N/mm^2
Flexural strength	20 N/mm^2
Tensile strength	5 N/mm^2
Water absorption	0.5%

IV-5-E-5 Cementitious Mortars.

Cementitious mortars shall be high strength polymer rich proprietary products which produce a dense durable mortar that exhibit minimum shrinkage on drying.

The polymer shall be acrylic, styrene-butadiene rubber or similar polymer which is durable in damp or wet conditions.

Cement shall comply with the Specifications except that cement to BS4027 shall not be used.

The mortar shall exhibit high bond strength and excellent adhesion and shall be free of chloride compounds.

The total chloride content of the mortar arising from the cement, aggregate and any other source shall not exceed 0.1% of chloride ion by mass of cement. The chloride content of the cement shall be determined in accordance with BS EN 196-21 and that of the aggregate in accordance with BS S 12: Part 1 17. The use of calcium chloride is prohibited.

It shall be non toxic suitable for contact with drinking water and it shall demonstrate excellent resistance to long term water immersion.

The minimum strength properties measured in accordance with BS 6319 at 28 days shall be as follows:

Compressive Strength	50 N/mm^2
Tensile Strength	5 N/mm^2
Flexural Strength	10 N/mm^2

IV-5-E-6 Sprayed Concrete

Sprayed concrete shall be microconcrete (Gunite) material.

The material shall be a proprietary pre-batched microconcrete supplied by a manufacturer who operates quality assurance procedures approved by the Engineer. It shall be cementitious with graded non-reactive aggregate modified with polymer. super plasticisers and silica fume and pre-bagged in the required proportions. Only water shall be added to the mix on site.

The water cement ratio shall not be less than 0.32 or greater than 0.45 and shall comply with the manufacturer's instructions.

The proportion of silica fume shall not exceed 10% by mass of cement.

The total chloride content shall not exceed 0.1% mass of cement. Calcium chloride or admixtures containing chloride salts shall not be used. The chloride content of the constituents of the mix shall be determined as follows:

Cement	-	BS EN 196-21
Aggregate	-	BS 812: Part 117
Admixtures	-	BS 5057: Part l

Maximum aggregate size shall be 3 mm.

There shall be no expansion agents contained in or added to the repair material.

The material shall exhibit excellent adhesion to the existing concrete and shall exhibit low shrinkage.

It shall have low water absorption and shall demonstrate excellent resistance to long term water immersion.

The minimum strength properties at 28 days shall be as follows:

Compressive strength	45 N/mm2
Flexural strength	10 N/mm2
Adhesive Strength	3 N/mm2

There shall be no change in source or type of material. manufacturer supply, mix proportions or method of mixing without the approval of the Engineer. Such approval will only be given after further site trials have been carried out to the satisfaction of the Engineer.

IV-5-E-7 Concrete

Concrete used in recasting shall comply with the specification to give a 28 day characteristic strength of 35 N/mm2.

Approved water reducing additives, superplasticizers, accelerators, may be used subject to satisfactory testing and the Engineer's approval.

IV-5-E-7-1 Priming

Concrete surfaces within the repair area shall be treated with a suitable bonding aid or primer which is compatible with the repair material.

Priming coats or bonding aids shall be thoroughly worked into all hollows and crevices in the prepared surface and around the reinforcement if required.

If at any time the primer or bonding aid completely dries out before over-laying, the repair surface shall be re-prepared generally by complete removal of the dried primer or bonding aid or as specified by the manufacturer of the repair materials.

When using cementitious based repair mortars the concrete substrate shall be thoroughly wetted to obtain a saturated surface dry condition. Any surplus water shall be remosted before reinstatement begins.

IV-5-E-7-2 Filling Resin Based and Cementitious Mortar

Mortars shall be applied in self supporting layers and in any case not exceeding the thickness specified by the manufacturer of the mortar.

Each layer shall be thoroughly worked and compacted into the repair zone and around or between reinforcing bars. The technique employed shall ensure that no air is entrapped and that full contact with the primed substrate is achieved.

Successive layers shall be applied as soon as the preceding coat has become sufficiently stiff to support the weight of the additional build-up layer but is still adequately tacky to provide bonding. The time between layers shall be in accordance with manufacturer's recommendations. If sagging occurs the material shall be completely removed and reapplied at a reduced thickness.

If at any time the last layer applied completely dries out before over-laying, the surface shall be prepared according to the manufacturer's recommendations.

The final build-up layer within a repair shall not be less than 10 mm thick and shall be leveled off or profiled to produce a smooth finish.

The repair shall be cured by the method and for the period recommended by the manufacturer of the repair system. During this period the temperature of the material shall not be allowed to drop below the minimum specified by the manufacturer and the repair shall be shaded from direct

sunlight. Curing membranes shall only be permitted where they are recommended by the manufacturer.

IV-5-E-7-3 Filling Sprayed Concrete

Delivery equipment shall be demonstrated to the satisfaction of the Engineer in site trials. The equipment shall deliver a conical uniform discharge stream of uniformly mixed material at the proper velocity from the discharge nozzle at all heights of the work.

Once placed, the applied material shall be capable of being profiled and steel trowel finished to a high standard without detrimental effects.

IV-5-F SPECIFIC WORKS

IV-5-F-1 Crack Repairs

Cracks requiring repair shall be categorized by the Engineer as follows:

- Live cracks.
- Major cracks.
- Stable structural cracks.

- **Repair of Live cracks**

Live cracks shall be chased out using a grinding machine to a minimum depth of 30mm and width of 15 mm.

The rebate shall be cleaned of loose material, primed and filled with a gun applied polyurethane sealant onto a debonding tape within the rebate.

- **Repair of Major Cracks**

Cracks classified by the Engineer as major live cracks shall be repaired by cutting out and subsequent restatement of the concrete.

Reinstatement shall be in accordance with the Engineer s instructions. A joint bridging strip shall be applied over the crack where instructed by the Engineer.

Where the Engineer instructs the concrete shall be cut out over sufficient width and depth to enable examination and any repairs to the reinforcement.

- **Repair of Stable Structural Cracks**

Stable structural cracks shall be filled with proprietary materials applied by pressure injection such that the crack is completely sealed.

Materials shall be polyurathane resin, epoxy resin or liquid silicate. Polyurathane foam may be used as directed by the Engineer for crack sealing in wet conditions.

The material shall exhibit low viscosity and good adhesion to dry or moist concrete. On curing, the material shall form a hard mass impermeable to water.

IV-5-F-2 Repair around pipe penetrations

Leaks around pipe penetrations, shall be repaired as follows:

Where pipes are in good condition the contractor shall chase out a 20 x 20 mm rebate around the pipe and fill the rebate with gun application of elastomeric polyurethane mastic sealant and provision of a butyl flashing ring.

Where pipes must be removed and new pipes installed the contractor shall break out and remove the existing pipe. The new pipe shall be installed complete with a puddle flange, and concrete

shall be placed from both sides of the wall. The contractor shall ensure a good bond will he formed between old and new concrete.

IV-5-F-3 Repair of leaking joints and Cracks

Repairs to leaking joints and cracks shall where directed by the Engineer be made on the internal water face using a proprietary joint bridging strip, with a minimum thickness of 2 mm and made of an inert flexible strip such as Hypalon (By Dupont) or equivalent material.

The adhesive shall be an epoxy resin compatible with the concrete and the flexible strips suitable for use in damp conditions. Full contact between the flexible strip and the concrete shall be ensured by means of a roller.

Surface preparation shall be by grit blasting or other approval method to remove all laitence and in accordance with the manufacturer's requirements.

IV-5-F-4 Sheet lining materials

Where directed by the Engineer water retaining structures may be repaired by means of a waterproof lining material. Lining materials shall include:

- Water proof rendering
- Water proof compound
- Sheet membrane

- **Water Proof Compounds**

Waterproof compounds shall be either polyurethane or methacrylate based. Surface preparation shall be by light scabbling proprietary acid etching or blast cleaning.

- **Sheet Membrane**

Sheet membrane systems shall be purpose-made materials such as "Hypalon" (by Dupont). Where the wall section is more than 3m high intermediate wall fixings shall be provided. All fixings of the membrane to walls, columns and penetrations shall be by propriety systems recommended by the membrane manufacturer. Joints shall be insitu solvent or heat welded. Surface preparation shall be by mechanical means to remove all surface protrusions and sharp arises which could perforate the sheet. The contractor shall demonstrate the lining system and its application in site trials.

IV-5-F-5 Refurbishment of Roof Structures

Where directed by the Engineer, all existing internal and external roof screeding, rendering and debris shall be removed from the roof and any defective concrete repaired.

Vents pots shall be installed before placing of any new roof screeding.

Where directed by the Engineer, concrete grade 20/10 screed shall be placed to provide a gradient of 1:100 from the center of the roof to the edge drainage points upon which water proofing shall be laid.

Insulation shall be provided by either expanded polystyrene board or by a 40 mm thick concrete screed as directed by the Engineer. Where no insulation layer is provided the waterproofing membrane shall be protected from U.V. radiation by an aluminum faced copping membrane.

PART IV – CIVIL WORKS

6. Waterproofing

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IV-6-A GEOTEXTILE SHEETS

Geotextile sheets shall be of the non-woven heavy duty type, needle punched or needle entangled and shall consist of long chain polymeric filaments of polypropylene, polyester, nylon or any material approved by the Engineer. The fabric shall be a stable network of fibres, which retain their positions relative to each other. The geotextile sheets shall meet the following requirements:

Property		Test reference
Grab strength	: 500N	NFG 38.014
Elongation, Minimum (at peak load) %	: 65/57	NFG 38.014
Puncture strength	: 1500N	NFG 38.019
Permeability m/sec	: $5.5x10^{-3}$	NFG 38.016
Minimum Surfacic weight	: 500 Gr/m^2	NF EN 965
Thickness under 2kPa	: 2.0 mm	NF EN 964-1

Geotextiles shall be furnished in rolls wrapped with protective covering to protect them against ultraviolet radiation and abrasion. Torn wrappers shall be repaired within 48 hours, using an approved protective covering. Each roll of fabric shall be marked or tagged to identify the manufacturer, type, length, width, and production identification number.

IV-6-B BITUMINOUS PUTTY

IV-6-B-1 Putty Filler

Putty filler must have a consistent, semi-rigid and compatible with flexibility inside the joint. Before fillings the joints must be dry and clean and the concrete surfaces in contact with putty must be primed with compatible material with the putty.

Putty must be of type "IGAS" or similar with bituminous base or rubber having the following characteristics:

Density : 15

Flexibility at 20° : null

Adhesivity of cohesiveness : 3 daN

Maximum elongation under service : 10%

Excellent adhesivity when laid on cement.

Another type could be used which is the elasto-plastic type conforming to the following requirements:

Black color

Temperature for use : 100°C to 130°C

Stable at : -30°C to 60°C

Penetration at 25°C : around 55°C

Softening temperature : around 145°C

Practical elongation : 10%

Non-toxic

The selection of which type to be used shall be approved by the engineer.

IV-6-B-2 Application of the sealant

Before proceeding with filling the joint, the Contractor shall complete the following works:

- Widening the joint by grinding or sawing when the joint width is less than required.
- Cleaning by grinding and brushing the sides of the joint all along its length.
- Final cleaning shall be done by blowing air immediately before starting the filling.

The putty is applied at a temperature ranging between 100°C and 130°C. It shall be filled in the joint from the bottom up. In case the putty spreads slowly when applied, especially in horizontal joints, more material is immediately added until the joint is completely filled.

IV-6-C WATERSTOPS

IV-6-C-1 General

Waterstops shall be PVC type or Vulcanized Caoutchouc class A (rubber water stop) and shall be installed where shown on the drawings or where directed.

The Contractor shall furnish the waterstops and all materials and equipment for splicing waterstops, for fastening waterstops to the forms and to the supporting reinforcing bars, and for completing the installation of the waterstops.

The Contractor shall provide suitable support and protection for the waterstops during the progress of the work and shall repair at the Contractor's expense any damaged waterstops, which in the opinion of the Engineer, have been damaged to such an extent as to affect the serviceability of the waterstops. All waterstops shall be protected from oil, grease and curing compound.

IV-6-C-2 Material

PVC waterstops shall be fabricated from a compound, the basic resin of which shall be domestic virgin PVC. No reclaimed PVC or manufacturer's scrap shall be used. The compound shall contain any additional resins, plasticizers, stabilizers, or other materials needed to ensure that, when the material is compounded, the finished product will have the required physical characteristics listed in the ASTM or similar.

IV-6-C-3 Fabrication

All waterstops shall be moulded or extruded in such a manner that any cross section will be dense, homogeneous and free from porosity and other imperfections.

IV-6-C-4 Installation

Installation of the waterstops shall be in accordance with these specifications and the manufacturer's recommendations. The location and embedment of waterstops shall be as shown on the Plans, with approximately one-half of the width of the waterstop embedded in the concrete on each side of the joint.

In order to eliminate faulty installation that may result in joint leakage, particular care shall be taken that the waterstops are correctly positioned and secured during installation. All waterstops shall be installed so as to form a continuous watertight diaphragm in the joint unless otherwise shown.

Adequate provision shall be made to completely protect the waterstops during the progress of the work.

Concrete surrounding the waterstops shall be given additional vibration, over and above that used for adjacent concrete placement, to assure complete embedment of the waterstops in the concrete. Larger pieces of aggregate near the waterstops shall be removed by hand during embedment to assure complete contact between the waterstop and the surrounding concrete. Where splices are required

between waterstops of different sizes, the splices shall be made as recommended by the manufacturer of the waterstop

IV-6-D WATERPROOFING PROTECTIVE COATING FOR WATER RETAINING STRUCTURES

IV-6-D-1 Description

This coating shall be a surface-applied material which waterproofs and protects concrete in depth and shall be suitable for use in water retaining structures. It consists of rapid-hardening Portland cement, specially treated quartz sand, and a compound of active chemicals. It is supplied in powder form and needs only to be mixed with water prior to application.

IV-6-D-1-1 Preparation of substrate

All concrete to be treated with this coating must be clean and have an "open" capillary system. Laitance, dirt, grease, etc. should be removed by means of high pressure water jetting, wet sandblasting or wire brushing. Faulty concrete in the form of cracks, honeycombing etc. should be made good. Surfaces must be carefully prewatered prior to the application of the coating. The concrete surface must be damp but not wet.

IV-6-D-1-2 Mixing

The powder material is mechanically mixed with clean water to a consistency of thick oil paint. Approximate mixing ratio is 0.8 parts water to 2 parts powder (by volume).

Materials mixed shall be as can be used within 20 minutes. Mixture should be stirred frequently. If mixture starts to set, no water should be added, the mixture should be stirred to restore workability.

IV-6-D-1-3 Application

The mix is applied by masonry brush or appropriate power spray equipment. When two coats are specified the second coat shall be applied while the first coat is still "green".

IV-6-D-1-4 Post Treatment

The treated surfaces should be kept damp for a period of five days and must be protected against direct sun, wind and frost by covering with polythene sheeting, damp hessian or similar.

IV-6-D-1-5 Safety

The use of rubber gloves and goggles during mixing and application is recommended.

IV-6-D-2 General Requirements

Waterproofing material shall be applied to interior concrete surfaces.

It is made of cement base, sand, and other chemical. It is composed of two contents:

Powder: Mixed of cement and other mixes as specified by the Engineer

Liquid: Resin base and other mixes as specified by the Engineer

The above product must be:

- Waterproofing
- Weather and chemical product resistant
- Not poisoned or unhealthy

Before placing waterproofing on concrete surfaces, a mastic of hydraulic cement base shall be used in concrete holes and cracks which provides a complete blockage to water. This mastic is a mixture of

powder placed in special can closed tightly and shall be mixed with water before usage as directed by the Engineer.

IV-6-E ELASTOMERIC SURFACE JOINT (COMBIFLEX)

This joint shall be as shown on the Plans and as specified herein. The joint is formed of an elastomeric sheet painted on both sides with a viscous resin coating and protected by an aluminium or copper sheet riveted on one side only.

The elastomeric sheet shall conform to the following requirements:

- Thickness 10/10 mm
- Resistance to rupture : 12 kg/cm²
- Elongation at rupture : 300%
- Modulus at 100% elongation : 85 kg/cm²
- Elongation at the elastic limit : 15%

The dimensions of the sheet, the method used in welding and the manufacturer's name shall be indicated. The resin shall be of a quality approved by the Engineer.

PART IV – CIVIL WORKS

7. Metal Works

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IV-7-A STEEL DOORS/WINDOWS

Steel doors and windows shall be fabricated from 3mm thick steel plate, framed and braced to form a rigid unit free twisting or wrapping. All joints shall be welded. The outer surface shall be weather resistant and have a smooth finish. Doors are to be supplied complete with all necessary accessories and hardware.

Doors and windows frames shall be steel and rebated to form a draught free weather proof installation.

IV-7-B HARDWARE

Hardware sets, hinges, bolts, doors closers, door stops, signs and other items of hardware, unless otherwise specified, shall be satin, anodised aluminum finished. Door hinges shall comply with BS 7352 whereas locks and latches shall comply with BS 8572. Door lock, latch lever and knob furniture are to be products of one approved manufacture.

For all hardware to be used, samples shall be submitted to the Engineer for approval.

IV-7-C GRILLS, SCREENS, ETC.

All grills, screens, protective meshes, louvers and guards shall be obtained from an approved manufacturers and shall be entirely suitable for their purpose.

All ferrous metal shall be galvanized, sherardized or coated with bonded zinc. All non-ferous metal shall be finished with an appropriate process to minimize corrosion.

IV-7-D COVERS AND FRAMES

Covers recessed for floor finishes shall be provided with galvanized rolled steel angles of height equal to the thickness of floor finishing and fixed to the surface of the structural floor slab along all edges of the trenches so that the top edge is level with the finished floor level. The angles shall be laid so as to form seatings for covers and all additional galvanized rolled steel tee. Sections shall also be provided to support the duct covers.

The covers shall be galvanized to suit the ducts and the seatings described above. A lightweight galvanized steel mesh shall be fixed to the upper surface of the trays to provide a key for floor finishes. The seatings and the trays shall be laid that the finished floor is perfectly level and all trays fully supported at all edges without the use of loose packings. At least one tray in every series of trays covering a length of duct shall be provided with cast-in lifting eyes and a pair of suitable lifting keys. The above shall be handed to the Engineer on completion.

IV-7-E FENCES AND GATES

Fences generally shall be in accordance with the relevant parts of BS 1722 Part 1 1986.

Chain link fencing shall be Type PLC.213 Grade A with 1.8 m high plastic covered chain link mesh. The mesh and line wires shall be galvanized prior to being plastic covered. The post shall be reinforced concrete.

The straining posts, intermediate posts and shall be manufactured and erected complete as specified in BS 1722. The fencing shall be true to line and vertical, following the profile of the ground, previously graded so as to prevent access beneath the bottom wire.

Gates shall be hung on adequate post, and shall be truly vertical.

Ornamental fabricated metalwork fences and gates shall be constructed of mild steel bar, strip or tube in accordance with the Drawings. All welded joints and drillings for bolts shall be made before

painting, and all bolts, nuts and washers shall be galvanized or plated with two coats of bituminous paint.

IV-7-F STRUCTURAL STEELWORK

Material for structural steelwork and workmanship shall comply with french standards. 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, mild steel electrodes and high yield steel as well as all structural steel fabrication shall comply with French Standards.

All structural steelwork shall be fabricated using welded joints where possible for shop joints and bolted for field assembly.

IV-7-G STAIRCASES

Staircases shall be suitable for superimposed load of 5kN/m² calculated on the plan area of the stair.

Open mesh type flooring shall be used for the treads and on the landings.

Stairs and landings shall be guarded on each side with a continuous handrail which shall be between 840 mm and 1000 mm in height on stairs measured from the tread nosings, and 1000 mm high on landings.

The riser / go dimensions shall fit the formula:

Twice the riser plus ONE TREAD = not less than 570 mm nor more than 635 mm. Consecutive treads shall overlap by not less than 16mm or as shown on the drawings.

IV-7-H LADDERS

Ladders shall comply with BS 4211 and shall be of galvanized steel and shall consist (unless otherwise indicated on the plans) of 65 mm x 12 mm flats and stringers 400 mm apart with 20 mm diameter solid rungs at a maximum of 250 mm centers shouldered and riveted over. Stringers shall have welded on feet and brackets for fixing to floors and walls, which fixings shall be not more than 2 meters apart. Brackets shall be 25 x 10 mm flats.

Stringers shall be extended 1000 mm above the upper platform and suitably opened out for access, or where ladders are below manhole covers, separate hand holds shall be fixed to the upper platform.

After fabrication, ladders under manhole covers shall dipped with hot galvanized.

The nominal diameter of steel tubing shall not be less than 32 mm.

IV-7-I HANDRAILING

Handrailing shall be approximately 1000 mm in height with an intermediate horizontal rail with standards not more than 2000 mm apart.

Handrailing shall be designed for horizontal loadings.

Standards and rails hall be manufatured from black mild steel or from extruded aluminum alloy approved by the Engineer. The nominal bore of steel tubing shall not be less than 32 mm.

Adequate provisions shall be made for thermal movement.

Steel handrailing shall be hot dip galvanized after fabrication.

IV-7-J RAILWAY

This work shall consist of furnishing and installing railways as and where shown on the drawings or as directed by the Engineer. The anchorage system shall be approved by the Engineer. The Contractor shall submit to the Engineer's approval all the elements and dimensions of the railway. The materials of construction of the railway shall be structural steel.

Structural steel used for railings shall conform with the requirements of the AFNOR.

All elements shall be protected by zinc coating (galvanizing, refer to paragraph 7L).

The anchorage system shall be such that damaged metal posts and rails can be readily replaced without the need for cutting or coping edge unit into which the anchorage is located.

During erection the railway units shall be securely held in their correct positions until all connections and fixings are complete and the post fixings have gained adequate strength to develop the full holing down moment. The assessment of the adequacy of the post fixing shall be subject to the Engineer's approval. The finished railways shall be true to line and level throughout their length.

IV-7-K STEEL ACCESS COVERS

Steel access covers shall be to the duty required and sized to suit the opening shown on the Drawings. They shall be complete with frame and shall be weatherproof (prevent the ingress of water) when closed and shall in all respects be strong and durable.

The covers shall be hinged and lockable and provided with stays to prevent the covers opening more than 105°. The Contractor shall provide with each cover a heavy duty non-corrodible padlock and four keys.

The covers and frames shall be galvanized or painted.

IV-7-L SLUICE GATES

IV-7-L-1 General

The Contractor shall furnish and install steel sluice gates complete with frames, seats, slides, stems, stem guides, lifts, stop nuts, stem covers, position indicators and anchor bolts, in accordance with the requirements of the Specifications and the Plans.

All steel frame angles, bars and plates below the water surface shall have a minimum thickness of one fourth inch. Two anchor bolts shall be provided about 6 inches below the top of the headwall for each gate to support the top of the gate frame. If a pipe extension is furnished, a bracket and anchor bolts shall be provided about 6 inches below the top of the headwall to support the pipe extension. All sluice gates shall have a manual lift mechanism. Manual effort required shall not exceed 18 Kg.

IV-7-L-2 Materials

The sluice gates shall be constructed from fabricated rolled steel plates, bars and shapes suitably reinforced to withstand applicable face pressure head. A pressure head shall be the vertical distance from the center of the gate to the water surface.

Capscrew, studs, assembly bolts and anchor bolts shall be stainless steel ASTM F593 or ASTM F594, alloy group 1 or group 2. All nuts shall be bronze ASTM B584 (CA 865, CA 863 or CA 873).

IV-7-L-3 Installation

The gates shall be installed as shown on the Plans submitted by the Contractor and approved by the Engineer and in such a manner as will prevent leakage about the seats. There shall be no leakage

between gate frame and concrete. Anchor bolts and other metalwork to be embedded in concrete shall be supported firmly and accurately in position while the concrete is being placed. Each lift shall be installed complete, and the stem and lift shall be lubricated in accordance with the manufacturer's instructions.

IV-7-L-4 Field leakage test

A field leakage test shall be performed by the Contractor after installation of the sluice gate. After all adjustments have been made and the mechanisms properly lubricated, each gate slide shall be operated through one complete cycle as a final check on proper operation before starting the leakage test. Seating and unseating heads shall be measured from the top surface of the water to the center of the gate.

IV-7-L-4-1 Seating Head

Under the design seating head, the leakage shall not exceed 0.1 gpm per foot (2.07×10^{-5} m³/s per meter) of seating perimeter.

IV-7-L-4-2 Unseating Head

Under the design unseating head, the leakage for heads of 20 ft (6 m) or less shall not exceed 0.2 gpm per foot (4.14×10^{-5} m³/s per meter) of seating perimeter. For unseating heads greater than 20 ft (6 m), the allowable leakage shall not exceed the rate per foot (meter) of seating perimeter specified by the following equations :

maximum allowable leakage

(gallons per minute per foot of seating perimeter) (Eq 1)

$= 0.10 + 0.005$ (unseating head in feet)

maximum allowable leakage

(cubic meters per second per meter of seating perimeter) (Eq 2)

$= 2.07 \times 10^{-5} + 3.15 \times 10^{-7}$ (unseating head in meters)

Where :

a = cross sectional area of gate disk (gate width x bottom rib plan dimension), square feet (square meters).

c = coefficient

P_3 accounts for the aspiration downward force when the gate is slightly open. it is significant only on large gates and higher heads. The coefficient varies with the shape of the gate lip. Downward pull may be greater than the weight of the gate and under some conditions it may be negative, indicating an uplift. The *c* coefficient can range from less than 0 to more than 1.0. One manufacturer suggests a coefficient of 0.5 for bullnose shapes and 1.0 for standard bottoms.

The above forces are based on the use of a handwheel, crank or electric-motor-actuated gate where the lift nut turns around a threaded rising stem or where the threaded stem turns inside a thrust nut on nonrising stem applications.

IV-7-L-5 Shop drawings

The Contractor shall submit, for the approval of the Engineer, manufacturer's SHOP DRAWINGS for the sluice gates he intends to install and their accessories. The dimensions of the gates shall be compatible with the size of the openings. These drawings shall be submitted before the execution of the related structural work. The Engineer's approval does not relieve the Contractor of his full responsibility for the manufacture, the installation and proper function of the gates. The Contractor

shall ensure that the proposed system is completely watertight, at the bottom, the sides and the top in accordance with paragraph 7L-4.

IV-7-M 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 .

All items to be protected shall be prepared as specified in the above standards.

Articles altered as the minor alternations at site or requiring minor repair at site shall be wire brushed to remove all rust and coated with 3 coats of approved zinc rich cold galvanized compound.

The minimum weight of coating and other requirements shall be as shown in the following table. If there is a conflict between the ASTM and minimum weight columns, the minimum weight column shall apply. The weight shown is ounces per square foot of surface area. The weight of coating shall be determined in accordance with ASTM A 90, modified to determine the coating of each surface separately. All surfaces, when tested separately, shall meet the minimum requirements.

Material	ASTM	Minimum Weight of Coating (oz./sq.ft.)
Steel products including structural shapes, tie rods, handrails, manhole steps, and miscellaneous items.	A 123 A 153 B 633 B 695	2.00 2.00 2.00 2.00
Hardware including cast, rolled, pressed and forged articles.	A 153 B 633 B 695	2.00 2.00 2.00
Bolts, screws, nuts and washers	A 153 B 633 B 695	1.25 1.25 1.25
CSP culverts and underdrains	A 444	1.00
Chain link fence fabric, tie wire only	A 392	1.20
Steel pipe (includes fence posts, braces and rails)	F 1083	1.80
All other chain link fence articles	A 123	1.80
Iron or steel wire fencing	A 116	0.80
Steel or iron sheets	A 525	1.20
Barbed wire	A 121	0.80
Electrolier standards, 7 gage steel and over	A 386	.00
Electrolier standards, under 7 gage steel	A 386	1.50

The zinc coating shall adhere tenaciously to the surface of the base material. The finished product shall be free from blisters and excess zinc, and the coating shall be even, smooth and uniform throughout. Machine work, die work, cutting, punching, bending, welding, drilling, thread cutting, straightening, and other fabricating shall be done as far as is practicable before the galvanizing. All members, nuts, bolts, washers, etc. shall be galvanized before a structural unit is assembled. All uncoated spots or damaged coatings shall be cause for rejection.

Products that are warped or distorted to the extent of impairment for the use intended shall be rejected.

Zinc coating which has been field or shop cut, burned by welding, abraded, or otherwise damaged to such extent as to expose the base metal, shall be repaired and recoated by one of the following methods :

IV-7-M-1 Hot-Dip Process

The damaged areas shall be thoroughly stripped and cleaned and a coating of zinc shall be applied by the hot-dip process.

IV-7-M-2 Metalizing Process

This process can not be used unless the Contractor has the approval from the Project Manager.

The damaged area shall be thoroughly cleaned by blasting with sharp sand or steel grit. The blasted area shall lap the undamaged zinc coating at least ½ inch.

Zinc wire containing not less than 99.98 percent zinc shall be used in the metalizing operation. A zinc coating shall be applied to the damaged area with a metalizing gun

to a thickness of not less than 0.005 inch on the damaged area, and shall taper to zero thickness at the edge of the blasted undamaged section.

IV-7-N WELDING

IV-7-N-1 Qualification

In addition to the welding of structural steel, all welding shown on the plans or ordered by the Engineer shall conform to the Standard Specifications for Welded Highway and Railway Bridges of the American Welding Society.

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, Part II, or such other qualification test acceptable to the Engineer. If required by the Engineer, the Contractor shall submit identifying stenciled test coupons made by any operator whose workmanship is subject to question. The Contractor shall require any welder to retake the test when, in the opinion of the Engineer, the work of the welder creates a reasonable doubt as to the proficiency of the welder. Tests, when required, shall be conducted at no additional expense to the Employer. Recertification 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 twelve (12) month period.

IV-7-N-2 Inspection of Welds

Radiographic inspection of welds will be required, as specified in the current edition of the Standard Specifications for Welded Highway and Railway Bridges of the American Welding Society. Additional welds to be inspected radiographically will be specified on the plans.

When specified on the plans, other methods of nondestructive inspection of welds will be required.

The Contractor shall secure the services of an approved organization qualified in the inspection of welds and will bear the cost of this inspection service.

Inspection of all welds shall be done only by persons skilled in such inspection and who are acceptable to the Engineer. The Engineer shall review and interpret radiographs and other non-destructive or destructive testing and has the sole authority to accept or reject the inspection or Works.

All film and/or other records of weld inspection shall become the property of the Employer.

In the inspection of welds, the presence of any of the following defects in excess of the specified limits will result in rejection of the weld as being detective:

Cracks Cracks, regardless of length or location, will not be allowed.

Overlaps. Overlaps, lack of penetration or incomplete fusion will not be allowed.

Inclusions, Including slag, Porosity and Other Deleterious Materials. Inclusions less than one and one-half (1.5) millimeters in the greatest dimension will be allowed if well-dispersed, such that the sum of the greatest dimensions of the inclusions in any twenty-five (25) millimeters of welded joint does not exceed nine and one-half (9.5) millimeters and there is no inclusion within twenty-five (25) millimeters of edge of a joint or a point of restraint.

Inclusions, Including Slag, Porosity and Other Deleterious Material. Inclusions one and one-half (1.5) millimeters or larger in greatest dimension will be allowed provided that such defects do not exceed the following limits:

a. Six and one-half (6.0) millimeters, for T up to nineteen (19) millimeters, one-third(1/3) T, for T from nineteen (19) millimeters to fifty-seven (57) millimeters, nineteen (19) millimeters, for T over fifty-seven (57) millimeters, where T is the thickness of the thinner plate being welded.

b. Any group of inclusions in line that have an aggregate length greater than T in a length of twelve (12) T will not be allowed.

Defects shall be removed by mechanical means or by oxygen grooving, after which the joints shall be welded again.

IV-7-O ROLLER SHUTERING

IV-7-O-1 General

The Control room downstream shall be utilized with roller shuttering doors enough to allow all kind of equipment necessary for installations and maintenance to enter and leave the room through these doors. These shuttering shall be made of stainless steel to ASTM A516 GRADE 70 or equivalent to any recognized International Standards. The mechanism of the shuttering shall allow operation by one person.

IV-7-O-2 Engineer's Approval

The contractor shall provide the address and complete information on the manufacture supplying the roller shuttering before placing any order, and shall submit full descriptions and details on the proposed shuttering and the ability of all its different components to withstand all operational conditions according to the dimension specified in the tender drawings.

Moreover, the contractor shall obtain the approval of the Engineer on the manufacture, assembling of all different components prior to furnishing and installing the roller shuttering door(s).

PART IV – CIVIL WORKS

8. Woodwork

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IV-8-A GENERAL

Woodwork shall include furnishing and installation of wooden doors, frames, kitchen cabinets, closet doors and all necessary materials and accessories of the sizes and combinations indicated on the drawings, specifications or in a manner approved by the Engineer.

Woodwork shall be in accordance with the last issue of D.T.U. No. 36.1

Woodwork shall be executed in coordination with other works namely, masonry, plastering and tiling.

The wood used shall be sound, dry, without knots, splits, fissures or imperfections.

Wooden pieces shall be stacked in a dry place, far from humidity.

IV-8-B FACINGS AND ASSEMBLING

All visible facings or faces shall be trimmed. Others shall remain unfinished.

The trimmed facings shall be raised in such a manner that no traces of sawing or imperfections remain. They shall be scraped and sanded.

All wooden pieces shall be adjusted and assembled with each other according to the best known processes such as mortise and tenon, dovetail, etc. Assembling done in workshops shall be glued. The glue shall be synthetic resin-based, stable, permanent and moth repellent.

Mortise and tenon joints shall be held by pins made of hard and dry wood or with metal pins. Junctions shall be executed deeply enough so that the tongues do not stick out of the slot.

Parts to be joined by slot and tongue shall be of parallel grain, the gap between the tongue and the slot shall not exceed 2mm. The false tongues shall be made of hard leafy wood.

The beds of the hinges shall be carved with a chisel to a depth of, at least, 1mm.

IV-8-C INSTALLATION

The installation shall be executed with accuracy and perpendicular plumb shall be respected.

The Contractor shall verify, on Site, the exact dimensions of the openings and shall take all precautions in order that the carpentry do not get deformed during setting and before the plaster dries.

The maximum play tolerated between mobile parts or between permanent and mobile parts shall be 1mm.

Leaves shall close automatically as soon as the handle is let go and without any necessity to make pressure on the door.

When closed, the doors shall be absolutely tight and the split hinges shall be vertical.

Door frames shall be fixed to walls or to concrete, each by means of seven sealing flaps and anchored well and deep enough as compared to the plastering. The length of the groove in the frame intended for fixing the sealing flap, shall not exceed the width of joint-cover.

All the used iron parts and notably the sealing flaps shall be coated with, at least, two layers of paint before using them. Each of them shall be long and shall have a section of 25mm.

The tip of the case side shall be fixed to the case by screws and not nails. The other tip shall be split.

Sealing shall be made with cement mortar well stuffed in the pending holes. The backside of the frames and all door or window frames in contact with the concrete or the masonry shall be coated with creosote, xylophone or any other similar protective product, before fixing.

All carpentry and wooden pieces shall receive a priming layer before the installation.

It is forbidden to use wedges or mastic to conceal the defects of the wood, or of the defective assembling. Mastic shall only be tolerated in order to cover a metal part embedded in the wood (nails, hinges).

IV-8-D HARDWARE

All hardware and various equipment shall be in accordance with the last NFP 26-303.

Samples of the various equipment shall be presented to the Engineer as soon as possible for the selection of the models that are to be used.

The Contractor shall supply all locks, split hinges, braces, handles, bolts, various door stops, automatic door pushers, stops, pegs, etc. unless otherwise specified by the Project Engineer.

All locks shall be of the best marks, safety locks with a mortise and a cylinder.

All internal one leaf doors shall comprise:

One safety lock with a mortise and a cylinder mechanism.

Three split hinges with 140mm blades, square ends, and a brass ring.

A pair of handles, Two plates, A door-stop.

Accessories shall be made of dull chromium-plated brass and shall comprise all necessary rings and washers for the installation and mounting of the hinges, leaving no play, and shall be approved by the Engineer.

Two-leaves doors shall comprise, in addition, three split hinges for the second leaf, two bolts, covers for fixing holes to be fixed on the tiling or in the wood.

IV-8-E PLYWOOD DOORS

Plywood shall be from the best quality with a thickness of 40 mm. at least and shall be approved by the Engineer. All framework shall be made from teak wood with a thickness of 50 mm.

PART IV – CIVIL WORKS

9. Painting

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IV-9-A DESCRIPTION

This work shall consist of painting work as shown on the plans.

IV-9-A-1 GENERAL REQUIREMENTS

Painting work shall conform to D.T.U. Standard No. 59.1.

Painting materials shall be of the best quality products of recognised manufacturer's and shall be subject to the approval of the Engineer.

The Contractor shall provide samples showing the brand, quality, and ingredients and shall be approved by the Engineer.

The Contractor shall follow the Manufacture instructions on the use of paint and shall be delivered to the site unopened with the original cover.

The Contractor shall submit for approval all types of paint he intends to use with manufacturer's certificate showing the following physical properties:

- Viscosity
- Adherence
- Durability
- Abrasion
- Permeability
- Resistance to washing
- Stability of color

All tests shall meet the requirements of U.N.P. and the Contractor is the sole responsible for these materials and their use for the particular job.

For concrete or plaster, mastic base water for gaps filling components shall compose of the following materials:

- Sealer 8.5%
- Water 25%
- Powder 40%
- Zinc 20%
- Oil 6.5%

IV-9-B PAINT WORK

IV-9-B-1 General

The Contractor shall supply all paints, primers, varnishes, distemper, oil, etc. ready mix in original sealed containers bearing the brand maker's name identifying the contents and giving directions for its proper use.

Painting materials shall be of the best quality products of recognised manufacturer's and shall be subject to the approval of the Engineer. The quality of the finishing colors shall be capable of giving three years minimum satisfactory performance under conditions of high temperatures and humidity, and capable of withstanding temperatures of up to 40 degrees C for long periods without color change. Paints shall also be resistant to oils, acids and alkalis.

The Contractor shall execute all paint works for flat concrete, plaster, wood, or steel as shown on drawings or as required by the Engineer.

The Contractor shall be extra careful to keep dust away before and during paintwork. Paint shall only be applied on a properly brushed surface, so as to eliminate all loose sand or mortar particles.

The application of paints, shall not be undertaken in a temperature over 30 degrees C or below 5 degrees C, in a humid atmosphere over 80% and when weather is dry, in a dusty or foggy, or rainy weather, or on frozen or overheated surfaces.

All hardware, furniture and accessories for doors and windows, together with any exposed electrical installation in walls shall be removed before painting commences. Upon completion of all paint work, all such hardware, furniture and accessories etc. shall be re-installed and left in a good working order.

Woodwork to be painted shall be reasonably dry and humidity must be less than 12% and its surface shall be cleaned and made smooth by sanding it with sand paper obliquely across the grain. The surfaces shall then be dusted off with a dusting brush and wood glue completely removed.

Surfaces of concrete to be painted shall first be washed down and then allowed to dry. Any efflorescence present shall be thoroughly removed, and the areas so affected shall be given a coat of porous alkali-resistant primer. After any traces of grease have been removed, the surfaces shall be painted with two coats of emulsion paint of the copolymer acrylic type. Any cracks in walls shall be cleaned, filled and puttied up then left to dry before application of paint.

IV-9-B-1-1 Paint on Concrete or Plaster

The Contractor shall prepare concrete or plaster surfaces to be painted as follows:

- Concrete or plaster surfaces shall be allowed to dry completely.
- Any signs of salt present shall be brushed away with steel brush then wait for a week. If salt reappears, it shall be brushed again and treated with phosphoric acid and zinc chloride.
- Check all cracks and holes in the concrete and putty them in special mastic.
- Sand paper concrete and plaster surfaces.
- Clean concrete and plaster surfaces from all dust, sand, oil, etc.

IV-9-B-1-2 Interior Oil or Water Base Paint on Concrete or Plaster with Mastic

After preparing concrete or plaster surfaces, painting shall be executed as follows:

- First coat - Prime coat (paste)
  - Apply first mastic layer. When dries, sand it with sand paper and clean it from dust.
- Second coat - 50% less fluid than the first coat.
  - Apply second mastic layer. When dries, sand it with sand paper and clean it from dust.
- Third coat - Color coat as required.
  - Check mastic and sand it with sand paper it, then apply mastic at needed locations.

Finally, apply two paint coats in conformity with the color approved by the Engineer either by brush or roller.

If the required paint is water base, mastic and prime coat shall be water base too. If the required paint is oil base, mastic and prime coat shall be oil base too.

IV-9-B-1-3 Oil or Water Base Paint on Concrete or Plaster without Mastic

After preparing concrete or plaster surfaces to be painted either inside or outside, painting shall be executed as follows:

- Applying a base coat with the required color.

- Repairing small holes with mastic then rubbing it with rough cloth until the textures matches the wall on it.
- Finally, applying two paint coats in conformity with the color approved by the Engineer either by brush or roller.

If the required paint is water base, mastic and prime coat shall be water base too. If the required paint is oil base, mastic and prime coat shall be oil base too.

IV-9-B-2 Exterior Paint Protection on Concrete

Concrete surfaces shall be prepared to paint by a base coat, and then paint brush with the required paint with one coat to reach a transparent cover, or two coats to reach a complete colored paint as required by the Engineer.

IV-9-B-3 Coarse Texture or Scratch Paint on Concrete or Plaster

Interior or exterior concrete surfaces shall be prepared to paint by a base coat the same color as the final coat, then applying the paint either by the roller or spray as required by the Engineer.

IV-9-B-4 IWoodwork

Woodwork shall be prepared for paint as follows:

- Wood shall be dry and humidity must be less than 12%
- Knots shall be sealed with knotting putty.
- Wood shall be rubbed and dusted off.
- Place special base layer on joints and leave until dry.
- Clean wood from all dirt.

IV-9-B-5 Woodwork with Mastic

After preparing woodwork, it shall be painted as follows:

- First coat - Prime coat (paste) and saturate wood well.
  - Apply first oil base mastic layer. When dries, sand it with sand paper and clean it from dust.
- Second coat - 50% less fluid than the first coat.
  - Apply second oil base mastic layer. When dries, sand it with sand paper and clean it from dust.
- Third coat - Color coat as required.
  - Check mastic and sand it with sand paper, then apply mastic at needed locations.

Finally, applying two paint coats in conformity with the color approved by the Engineer either by brush or roller.

IV-9-B-6 Wood Paint with Varnish or Clear Lacquer

After preparing woodwork, it shall be painted as follows:

- If the requirement to have the wood color painted, apply by using a brush or sponge one coat or two to get a deep color.
- If required, fill wood holes as required by the Engineer and sand it with sand paper to the Engineer's satisfaction.

- After drying, rub the wood with sand paper and clean it from all dirt and dust.
- Apply three coats of slow drying varnish at least, or spray three or more coats of fast dry lacquer as approved by the Engineer. After drying, rub and polish.

IV-9-B-7 Metal Work

Metalwork shall be prepared for paint as follows:

- All metalwork shall be cleaned free from all rust, scales, grease, oils and any other surface stains.
- Cracks and holes shall be filled with steel mastic and sand cleaned, then dusted.
- Two prime coats matches the specified color if possible.
- Two coats of finish paints as required by the Engineer.

In cases where protection coat against water and chemical effects, special prime and base paint (i.e. epoxy for water) shall be used to resist such effects as approved by the Engineer.

IV-9-B-8 Liquid Epoxy Coating

IV-9-B-8-1 Description

The coating shall be based on liquid, chemically cured epoxies. The curing agent may be an amine, amine-adduct, or polyamide. Materials used in both the primer and finish coats shall be products of one manufacturer.

The coating shall be suitable for use in irrigation water. It shall be used for steel sluice gates, pipes and for mechanical couplings, flanges and similar appurtenances for steel pipe fittings and specials as well as to nuts, bolts, and other items used in conjunction with connections and attachments.

IV-9-B-8-2 Surface Preparation

- The surfaces shall be first cleaned to remove oil, grease or other foreign matter. Only approved solvents that do not leave a residue shall be used.
- The surfaces shall be abrasive blast cleaned with sand, steel shot or grit, to achieve a near-white metal surface.

IV-9-B-8-3 Application Of Epoxy Coating System

The coating system shall be applied as recommended by the manufacturer. It shall consist of:

- A two-part, chemically cured epoxy primer.
- Two coats of a different two-part, chemically cured epoxy topcoat.

IV-9-B-9 Safety & Cleanliness

The Contractor shall keep all painted works until the end of the project. In case of damages or deterioration, the Contractor shall repair them on his own expense as required by the Engineer.

The Contractor shall protect all painting works during execution and if needed, shall place covers to prevent dust, and shall clean all areas affected by paint drops during work. Finally, at the end of the project, the Contractor shall deliver all paintwork in a perfect way.

PART V - Mechanical Works

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V-A GENERAL

Any non-metallic materials such as may be employed for bellows, packing or sleeves, coatings or linings etc. liable to come in contact with any kind of water shall be approved by the Engineer.

V-A-1 Fasteners

All bolts, nuts, studs and stud bolts, including those required for installation at terminal points to existing equipment, shall be provided by the Contractor and approved by the Engineer and shall have metric threads to BS 3643.

After tightening, the minimum engagement of the thread shall equal the thickness of the nut. The projection of the thread beyond the outer face of the nut shall not exceed one quarter of the outside diameter of the thread. In no circumstances shall galvanized or coated bolts be shortened by cutting.

Washers shall be provided under all nut and bolt heads.

All fastenings and accessories in contact with the process water shall be of stainless steel, cadmium plated mild steel or other corrosion resistant material subject to the approval of the Engineer. All bolts, nuts, screws, washers and other fixings for anchoring the plant to walls, floors, ceilings, etc. shall be of corrosion resistant material or shall have a protective surface treatment to the approval of the Engineer.

All bolts in inaccessible positions shall be secured by either self locking nuts, spring washers and nuts, or castle nuts with split pins. Fasteners associated with items requiring removal during routine maintenance shall be of stainless steel. All other items shall be sheradised or hot dip galvanized in matched condition.

All holding-down or foundation bolts shall be supplied and shall be complete with hexagon nuts and washers. Bolts of steel round bar formed into a loop at one end are not acceptable.

V-A-2 Fastenings to Concrete or Masonry

Anchor bolts for the fixing of small items shall be of the torque-expanded type of approved make, installed strictly in accordance with the manufacturer's instructions. The size of hole required shall not exceed 38mm.

Where the base material will not withstand the expansion stresses imposed by the torque-expanded type or where the highest degree of resistance to vibration is required, an approved type of chemically bonded anchor bolt may be used.

The minimum distance from any concrete edge shall be 100mm for expanding type fixings and 75mm for embedded bolts.

V-A-3 Base Plates

Separately mounted items of plant which are required to maintain an accurate alignment shall be mounted on a common base plate, together with all associated items and guards.

The base plate shall be of rigid construction, machined on all mating surfaces and drilled for foundation fixings. Machined datum faces shall be provided and leveling facilities incorporated in the underside.

Provision shall be made for the easy removal of any section of the drive and positive re-alignment using dowels or other approved means. Shims and packings shall be kept to a minimum and clearly identified for re-assembly.

All drain points on the assembled plant are to have easy access and drain piping shall extend beyond the base plate.

V-A-4 Protection of Moving Parts

All moving parts where accessible to operational personnel shall be protected and guarded to meet to relevant regulations. All guards shall be designed to facilitate easy removal and maintenance.

V-A-5 Balancing

All rotating parts of the machinery shall be statically and dynamically balanced unless otherwise agreed in writing by the Engineer. The complete rotating assembly shall be designed such that any critical speeds are outside the duty running speed range of the machine.

V-A-6 Lubrication

Any components requiring manual lubrication shall be provided with greasing nipples of an approved type mounted on a panel and identified.

A remotely mounted electrically operated lubricator of approved type shall be provided to serve components, if any, requiring continuous lubrication by external mechanical means.

The lubrication tubes, if any, shall be of approved material suitable for high pressure use.

The Contractor shall include all grease and oil required for testing at works and site.

The first filling after tests shall be provided by the Contractor who shall submit details of his recommended lubricants, which shall be available from any of the major oil companies, for approval by the Engineer.

All bearing surfaces shall be properly charged with grease before the plant is operated.

V-A-7 Nameplates and Labels

Instruction plates, nameplates and labels shall be provided for all items of the plant giving particulars of duty, size, serial number and full information for identification and operation. Their construction and engraving shall be to the Engineer's approval.

V-A-8 Plant References

After final painting, all plant items shall be identified by a unique reference character as detailed on the specification drawings or otherwise specified. Such references to be affixed in a prominent position on the plant body with characters not less than 100mm high or as otherwise specified. Characters shall be bold capital letters and/or numerals. The abbreviation `No' shall not be used.

Unit references shall include any associated main and auxiliary drives and shall follow a logical sequence based on layout or history. In any particular installation, a set of similar duty drives where any number of units may run shall be suffixed 1, 2, 3, 4 etc., whereas alternative drives for the same duty where only one unit may run (ie.duty/standby) shall be suffixed A & B.

V-A-9 Tools and Tackle for Maintenance

The Contractor shall supply a complete set of any special tools and other equipment necessary for the dismantling, re-erection and adjustment of the plant approved by the Engineer.

The tools provided shall be in new condition, adequately labeled as to their use and contained in stout and suitable padlocked boxes. The Engineer's instructions as to who shall be the recipient of the tools shall be sought before delivery is made.

Any special slings required shall be provided and clearly marked by embossed labels to show safe working loads. Test certificates shall be provided where applicable.

V-A-10 Locks and Keys for Mechanical Plant

All locks of the same size shall be of the same type and manufacture but having different keys.

Three keys shall be provided for each lock.

Each key shall have permanently attached to it an embossed brass label stating the following:

- Key number
- Location of lock/Item of equipment

A master key for all mechanical rooms.

V-A-11 Noise Level

All plant shall run without undue vibration and with the least practicable amount of noise.

Vibration levels shall not exceed these set cut in ISO 2372 for the particular type of equipment.

Any items of plant which produce a noise level exceeding 65 dB (A) at 3 meters shall be listed by the Tenderer. It shall be deemed that all items of plant not so listed have a noise level of less than 65 dB (A) at 3 meters.

To meet the environmental requirements, the Contractor shall provide all necessary equipment to meet the following conditions, based on the site layout shown on the specification drawings and with 75% of the plant running simultaneously:

- the noise level generated at the site boundary by any new plant shall not exceed that generated by the existing plant.
- the noise level at 100m from the source does not exceed 65 dB (A).
- the noise level in the building (10m from the source) does not exceed 70 dB (A).
- the noise level in the plant room (5m from the source) does not exceed 80 dB (A).
- Warning notices shall be provided at all entrances to rooms where the noise level will exceed 75 dB (A).

V-A-12 Frost Protection

The plant shall be adequately protected against damage from freezing, using an approved means of insulation.

Particular attention shall be given to pipework, pump casings, etc. and any part of the plant and equipment likely to stand for periods charged with static water.

Where lagging is used, it shall be suitable for outside installation and completely impervious to all weather and atmospheric conditions on the works. Lagging materials containing asbestos shall not be used.

The lagging shall be sectional and easily removed for maintenance purposes. Joints shall be sealed together with an approved waterproof adhesive tape.

Areas where lagging may be vulnerable to damage shall be suitably protected by an approved means.

V-A-13 Corrosion Protection

Where dissimilar metals are in contact or close proximity and corrosion may occur through electrolytic action or differences in electrical potential, protection shall be afforded by electroplating, suitable gaskets, cathodic protection or other means approved by the Engineer.

Chromium plated parts shall not be used on sewage works or in any other damp or corrosive atmosphere.

All surfaces shall be adequately protected in transit, and any damage shall be renovated immediately on off-loading and on completion of erection.

After cleaning and inspection but before the plant leaves the Contractor's works, the machined surfaces of steel and ironwork shall be covered with a preserving fluid of an approved type.

All external steel screw fixings shall be supplied in the galvanized condition, stainless steel, or sheradised to comply with BS 4921, Class 1 or Class 2 with passivation treatment.

V-A-14 Surface Preparation and Painting

The whole preparation and paint system shall be suitable for the operating environment specified and a painting schedule giving details of preparatory treatment, types of paint, number of coats and method of application shall be submitted with the Tender.

Proprietary items may be used in their standard finish subject to the approval of the Engineer. For specified applications, adequate supervision shall be provided for all stages of preparation, application and testing.

All steelwork shall be protected in accordance with BS 5493 and based on a “long” time to first maintenance. The exterior environment shall be regarded as “polluted inland” (Table 1 Pt. 2) and the interior environment shall be regarded as “frequently damp” (Table 1 Pt. 7) unless otherwise specified. Items below water level or subject to immersion shall be treated as Table 1 Pt. 8.

After all machining, forming and welding has been completed, all steelwork surfaces shall be thoroughly cleaned of rust, scale, welding slag or spatter and other contaminations prior to any painting.

The system proposed shall be abrasion resistant and conform to the following typical requirements.

Preparation of steelwork at the works shall be either:

- Hot dip galvanized to BS 729 with a median thickness of 85 microns (0.0034") or
- Grit blasted to BS 7079 Grade SA 2.5 and zinc sprayed within 4 hours to BS 2569 Part 1 to a thickness of 125 microns (0.005") followed by one coat of approved etch primer.

Typical finishes (with compatible primers) based on BS 5493 are given below.

a. Steelwork and ferrous castings exposed above water/sewage level

   Either high build micaceous iron oxide or chlorinated rubber to give a minimum total dry film thickness of 300 microns or, one coat of two pack epoxy primer and further coats of epoxy paint to give a total dry film thickness of 270 microns.

b. Steelwork below water/sewage level

   Either epoxy system as above or coal tar epoxy paint system to give a minimum total dry film thickness of 450 microns.

c. Ferrous castings and fittings without substrate below water level

   Coal tar epoxy paint system to give a minimum total dry film thickness of 450 microns. These coatings shall be subject to an approved test by the Engineer.

The surface of all non-ferrous parts usually painted shall be cleaned, rubbed down, stopped, filled and given one priming coat of paint.

Anti-corrosion coatings for any steel or iron used in pipework, pumps, valves, etc. in contact with potable water, shall be either a compatible bitumen material to BS 3416 or a polymeric anti-corrosion coating complying with Water Industry Specification WIS 4-52-01.

Any damage occurring to any part of a painting scheme shall be made good to the same standard of corrosion protection and appearance as that originally employed. Any finish coat applied on site shall be considered for decorative purposes only.

Manufactured articles to be galvanized shall be hot dip galvanized after complete fabrication and no bending, cutting, drilling, riveting or threading shall be permitted after galvanizing.

The care of galvanized articles when transporting, storing and erecting them shall be in accordance with the recommendations of BS 729. The renovation of small areas of damaged coating not exceeding 40mm² shall be in accordance with Appendix D of BS 729 and subject to the Engineer's approval.

V-A-15 Pumps and Transmission

V-A.15-1 Pump Duty

Pumps shall be of the type specified and arranged as indicated in the drawings. They shall be designed to give specified output against all losses including those relating to the pump.

The Contractor shall match his pump characteristics to the pipe system network to achieve high pump efficiency and reliability.

Each set must be capable of running satisfactorily in parallel with other sets in the system without throttling and by itself, without cavitation or overload under all operating conditions within the system characteristics given.

The pump section and arrangement shall be such as to ensure that the head available exceeds the N.P.S.H. requirements of the pump under all operational conditions.

Where the system and pump characteristics are such as to give rise to the possibility of surge in the pipeline with consequential damage, a surge investigation shall be undertaken if the results of the investigation show that there is a problem measures shall be proposed by the contractor to alleviate the problem. These measures shall be agreed with the Engineer.

Centrifugal pumps shall have a non-overloading characteristic over the complete range of head and quantity delivered and the drive shall be capable of starting the pumps against a closed valve, i.e. maximum pump head conditions.

The whole pumping unit shall be capable of withstanding without detriment, reverse rotation to a speed that would occur if the pump were to stop when the differential head was at a maximum and the delivery and/or non-return valve failed to close.

For sewage pumps the ability to operate with the maximum reliability is of prime importance, with efficiency being a secondary consideration. The pump shall therefore operate without clogging, being designed to pass a sphere of 125 mm dia. where the size of the delivery mains permits. Whilst the pumps shall be designed to meet a specific duty they shall also be capable of operating over the duty range specified for prolonged periods and for standing idle for long periods without attention as in the case of storm pumping.

V-A.15-2 Centrifugal Pump Casings

Pump casings shall be of the volute type and shall be capable of withstanding all pressures which may be produced due to operating pressure surges.

Particular attention shall be paid to the wear characteristics of the pumps. In the case of sewage pumps, due to the presence of grit in the sewage wear, could be appreciable.

The pump design shall ensure that alignment is maintained between the various assemblies by recesses, spigots and dowels and shall be such that all components liable to wear can be replaced.

Components shall be permanently marked with the manufacturer's number and where dowels are not used, permanently marked for correct assembly. The pump casing and the pump impeller should normally have detachable wear rings.

The casings of the pumps shall be of a suitable grade of close-grained gray cast iron or nickel iron and have flanges to match the specified pipework.

The waterways through the pumps shall be smooth in finish and free from recesses and obstructions.

Sewage pump casings shall be of substantial construction to give long life under abrasive conditions and suitably stiffened to withstand shock due to solids in suspension. Inspection holes shall be provided in any section bend and in the pump casing above the impeller for access to facilitate the clearance of obstructions. The inspection hole covers shall be shaped to conform to the interior profile of the waterway when in place and shall be fitted with starting screws where necessary.

V-A.15-3 Impellers

Impellers shall be securely fitted to pump shafts in such a manner to prevent them becoming loose or detached when the pump is in operation, or when rotating in the reverse direction, either by liquid flow or motor rotation.

The impellers and guide vanes (if any) shall be manufactured from a suitable material, accurately machined and smoothly finished to minimize hydraulic losses.

The rotating elements shall be statically and dynamically balanced before final assembly. The impeller shall be readily withdrawable from the pump casing without the need to disconnect pipework.

For sewage pumps the impeller shall be of the open type with the inlet ends of the vanes being of bulbous design and the impeller passages being as large as possible consistent with good performance.

The inlet ends and surfaces of the vanes shall be dressed to give a smooth finish to prevent fouling by rags and fibrous matter within the pumps.

Impellers for both sewage and storm water pumps shall be of the non-shrouded type, constructed normally of close-grained gray cast/nickel-iron, and designed to exclude gritty matter from the shaft and gland.

Clearance at the eye rings and wear plates shall be kept to a minimum, and where it is found necessary to cut back the impeller this is to be done on the vanes only.

V-A.15-4 Pump Shaft

The pump shaft shall be of high tensile or stainless steel adequately sized, with good fatigue, shock load and corrosion resistance. The duty speed range shall be well below the first critical speed of the shaft. Where a change in diameter of the shaft occurs the shoulder shall be radiussed or undercut to the appropriate BS to reduce stress concentration.

The shaft shall be complete with easily renewable stainless steel protecting sleeves at glands and bearings.

V-A.15-5 Shaft Seals

Pump shaft sealing arrangements shall be suitable for the water pressures and shaft speeds involved.

Pumps fitted with soft re-packable or packed gland type, seals shall have stuffing boxes designed to facilitate adjustment or replacement of the packing materials.

Pumps shall be fitted with a split type mechanical shaft seal arranged such that replacement of wearing components can be carried out without the need to dismantle the pump.

Special care in the selection of materials shall be taken in order to avoid binding and electrolytic action between the shaft sleeve and the mechanical seal components, particularly where long periods of idleness are inherent in the duty cycle as in the case of standby and storm pumping.

Each mechanical seal shall be equipped with leakage collection facilities and separately piped as specified.

V-A.15-6 Bearings

All pumps shall incorporate bearing arrangements which prevent the escape of lubricant into the liquid being pumped. The bearings shall be located in dust/moisture-proof housings.

All bearings shall be liberally rated to ensure cool running and meet the load factors specified.

For vertically mounted pumps, the top bearing shall be a combined thrust and journal type, designed to prevent any thrust loads being transmitted to the drive motor. The pump bottom bearing shall be lubricated by an enclosed water lubricated sleeve bearing for potable water applications but by grease or other approved means for sewage use. Storm pump bearings shall also be suitable for standing idle for periods up to 2 months without attention or movement.

Where grease points are necessary they shall be fitted with removable screwed plugs which shall be accessible without removing guards. All bearings having automatic lubrication shall also have provision for hand lubrication.

V-A.15-7 Base plates and Stools

For vertical pump units, heavy cast iron or fabricated steel floor plates and motor stools shall be provided for direct mounting on concrete floors or supporting steelwork. Suitable journal and thrust bearings shall be provided in the baseplates to carry the vertical drive shaft.

Where necessary the motor stools shall be designed to accommodate flywheels and bearing housings.

Floor plates shall be recessed and so arranged that the tops and fixing bolts are level with the finished floor.

The pump units shall be accurately aligned and located on the baseplate by set screws and parallel dowels or machined spigots. Approved means of dowel withdrawal shall be provided.

V-A.15-8 Lubrication/Cooling Monitoring

A lubrication system shall be arranged for the lubrication of all grease points on the pumps and shafting from motor room level. Individual bearings within the support tunnel tubes and on the pump sets themselves shall receive separate supplies of grease fed by pressure tubes laid from each bearing to battery plates readily accessible from motor floor level for grease gun operation.

Pressure tubes shall be grouped together where possible and securely attached by brackets, straps etc. to tunnel tubes, with connectors located near to the motor support plate for easy removal of shafting in the event of maintenance work. In exposed positions pressure tubes are protected from damage. Motor grease points will not be included in this lubrication system but shall receive individual attention.

The battery plates shall have sufficient greasing points for all bearings and be located on or adjacent to each pump motor stool.

A notice is to be supplied and fixed on the wall in a prominent position detailing the manufacturer's recommended greasing schedule. The notice shall include a warning of the dangers to bearings from “over greasing”.

A grease gun shall be supplied for all greasing purposes.

Bearings which require a continuous supply of lubricant shall incorporate a means of monitoring such a supply, either by flow or temperature rise as appropriate for the type of bearing employed; separate monitors being fitted for each bearing feed or housing.

Such monitors shall include all necessary ancillary power or pulse counting devices to enable the operation of any monitor to initiate a volt free contact rated at 240V 0.5A AC.

V-A.15-9 Pump Tundish

Where specified, each pump shall be equipped with a cast aluminum or fabricated steel tundish to accommodate the drain lines from mechanical seals, casing vent and other minor drainage points on the pump. A single drain pipe shall be run from the tundish to the house drainage system.

V-A.15-10 Air Release Cock

The highest point on the pump casing shall be fitted with a manual air release cock having a removable handle or an automatic air release valve with a lockable isolation valve as specified. Air release pipework on sewage pumps shall be not less than 30mm bore and shall discharge back into the wet well at high level and have facilities for rodding. The drain from each air release cock shall discharge via pipework as specified.

V-A.15-11 Couplings

All couplings shall be of an approved type and the Contractor shall arrange for the provision and fitting of both coupling halves to each respective shaft and shall include for all necessary modifications to any existing shafts to be coupled.

Where specified, the Contractor shall include any equipment required to prevent damage to any part of the drive in the event of reverse rotation of the pumps.

V-A.15-12 Intermediate Shafts

Intermediate shafts between the pump and drive shall include universal couplings at each end allowing free axial movement to avoid end thrust being transmitted. The shaft and coupling shall be fitted with a full length guard manufactured from mild steel mesh on a mild steel framework, easily removable for maintenance purposes.

The frame and mesh shall be hot dip galvanized.

V-A.15-13 Gear Unit

Each unit shall be continuously rated to transmit the full power of the drive either directly in line or through a right angled, helical gear system, having an input/output speed ratio to suit the duty.

The gear case shall be made of substantially ribbed cast iron with machined mounting feet and shall form a totally enclosed, oil tight casing.

The gear unit case and bearings shall be designed to accommodate the total weight of any suspended drive shafting and couplings in addition to any dynamic load imparted during service, and run for a minimum of 10,000 hours before a major overhaul is required.

Where specified, an electric tachometer shall be fitted to indicate the output shaft speed.

V-A-15-13-1 Lubrication

The gear unit shall be grease or oil lubricated, arranged to provide an adequate supply of lubricant for the duty.

Where oil lubrication is employed, the casing shall include an oil breather, level indicator and drain plug.

Units having a rated output greater than 500kW shall have inspection covers and include a forced lubrication system comprising an oil circulating pump, reservoir tank and full flow “Duplex” type oil filters having re-usable elements together with associated pipework; the oil being circulated by either (a) an internal mechanically driven gear pump and an external electrically driven pump arranged to prime the gears as pre-set timings as recommended by the unit manufacturer, or (b) duplicate external electrically driven pumps, each of which may be selected to prime at pre-set intervals and run when the gear unit runs.

Such a lubrication system shall include dial gauges and alarm switches to monitor high oil temperature and low oil pressure.

V-A-15-13-2 Reverse Rotation

Where specified, the gear unit shall be capable of withstanding reverse rotation for a limited period with no detriment to the unit. Where a forced lubrication system is used, this shall continue to operate satisfactorily under such conditions.

V-A.15-14 Submersible Sewage Pumps

The pumps shall be fully submersible and of the unchokeable type, capable of passing raw unscreened sewage. They shall have non-overloading characteristics and incorporate bearings sealed for life.

The sealing arrangements between pump and motor shall be by means of mechanical seals running in an oil bath which serves to lubricate and cool the interfaces of the seals.

The pump shall include renewable and easily replaceable wear rings.

Robustness of construction and the ability to operate automatically with a minimum of attention for long periods is essential.

The pumps shall be supplied with guide rails unless otherwise stated, and particular attention shall be given to the free passage of the pumps up and down the rails without jamming. The pump outlet flange, unless otherwise stated, shall have a boltless coupling on to the flange of the fixed delivery pipework and shall have positive location so as to provide an automatic coupling with a good seal when the pump is lowered into position.

The pump casing shall incorporate a lifting eye of not less than 80mm internal diameter suitable for the attachment of heavily galvanized lifting chains which shall be brought out of the wet well to a conveniently sited fastening.

V-A.15-15 Progressive Cavity Pumps

The pump casing shall be manufactured in a close-grained cast iron in accordance with BS 1452, or in grades of stainless steel to suit the nature of the pumped liquid. The pump casing shall be pressure tested in accordance with BS 599.

The pumping element shall consist of a single helical rotor revolving within a resilient stator. The stator/rotor shall be designed in accordance with the normal operating conditions, taking into consideration temperature, corrosion, abrasion and reliability under maximum torsional load. The rotor material shall be stainless steel either ceramically coated or chrome plated in accordance with the relevant requirements of BS 970: Part 1.

The rotor's eccentric motion shall be facilitated by either a flexible drive shaft or by fitting a universal joint between the motor and drive unit. This motion shall permit a continuous seal line throughout the pumping element thus giving a constant positive displacement. The flexible or coupling rod drive shall be of a high strength stainless steel with an impermeable thermoplastic or equal coating to provide resistance to abrasion and corrosion.

The pump drive assembly may be directly coupled or arranged for a guarded toothed-belt drive arrangement. The pump speed shall not exceed 500 rpm.

Under no circumstances shall any grade of aluminum be employed in the fabrication of the pump's wetted parts.

All working surfaces shall be accurately machined and provided with deep registers, where necessary, to ensure true accurate alignment. The pump casing shall be capable of being fitted with a replacement rotor and stator components. Tapped bosses shall be provided for drainage purposes and suction and delivery gauge connections.

V-A.15-16 Screw Pumps

Screw pumping units shall be suitable in all respects for pumping crude sewage and returned activated sludge and for running continuously at all outputs up to the specified maximum. All parts and components shall be fully weather-proof and suitable for use out of doors.

V-A-15-16-1 Drive Arrangement

Each pump shall be driven by an electric motor, the drive being transmitted from the motor to the screw, either directly through a reduction gearbox or else through a V-belt drive and gearbox. The gearbox shall have oil bath lubrication and shall be provided with an inspection cover, oil breather and oil level indicator. The gears shall be rated for continuous duty.

Connection between the drive unit and screw shall be by means of a pin-type flexible coupling with rubber bushes, or other approved flexible coupling.

If a V-belt drive is used ready means of belt tension adjustment shall be provided.

Means shall be provided to prevent reversal of rotation on shut down.

V-A-15-16-2 Bearings and Lubrication

Each pump shall be complete with top and bottom bearings, driving mechanisms and automatic lubricators, all supplied and installed as a unit by one manufacturer.

The top bearing shall be designed to accommodate the main radial and axial loads which occur on the screw and shall be suitable for high pressure grease lubrication. The bottom bearing shall be of the bronze sleeve type secured in a watertight cast iron housing and designed to accommodate radial forces and end support load. The housing shall be mounted on a fabricated steel pedestal and plate which shall be swivel mounted to allow them to take up correct alignment on installation. The bearing shall be fitted with an external stationary shroud to prevent debris affecting the moving parts.

Lubrication shall be automatic from a grease or oil lubricator, the lubricator pump being driven by an electric motor or from the main drive. A friction drive is not acceptable. Oil shall be returned from the bearing to the oil reservoir.

In the case of an electrically driven lubricator the electric drive shall be interlocked with that of the main pump drive so that the screw pump will not run without the lubricator. A warning light shall indicate `lubricating pump failed'. Where other means of driving the lubricator pump are used provision shall be made to stop the screw pump if the lubricator drive fails for any reason.

V-A-15-16-3 Installation and Guards

Each screw pump shall be suitable for mounting in a concrete trough and shall be supplied complete with steel side profile member. Each screw shall also be supplied with a steel splash plate to fit round the shaft and seal the hole where the upper end of the screw passes through the wall into the motor room. The screw and its driving mechanism shall be such that they can be safely used to form the final screed of the concrete trough in which the screw rotor runs.

All equipment offered shall be designed to keep maintenance to a minimum, and to provide maximum safety to operatives and maintenance staff. Protective guards shall be fitted over all moving parts to prevent any possible contact.

V-A.15-17 Double Disc Pumps

The double disc pump shall comprise two reciprocating, mechanically driven, tough resilient discs with a sufficiently large cavity between the discs to produce displacement in a smooth continuous flow.

The pump shall be valveless and glandless and be capable of operating dry indefinitely without pump damage occurring.

The double disc pump shall be available as a static or mobile unit, as specified. It shall be suitable for either electric motor or diesel engine drive, as specified.

The pump body shall be manufactured from cast iron to BS 1452 Grade 220, as a minimum.

The discs shall be manufactured from Nitrile rubber or equivalent.

V-A.15-18 Diaphragm Pumps

The pump shall be of the diaphragm type utilizing a bullfrog type valve, suitable for pumping viscous solutions containing solids up to 55mm diameter as specified. It shall be driven by an electric motor through an oil bath reduction gear unit.

The main body of the pump shall be manufactured and all wetted parts shall be supplied.

The diaphragm shall be manufactured from neoprene, nitrile, hyperlon or viton elastomers and shall be reinforced with polyester fabric.

V-A.15-19 Submersible Borehole Pumps

Pumps impellers shall be closed or semi open type made from zinc free bronze or such other material required for use with the particular water to be pumped.

Pump bodies shall be of zinc free bronze or such other material as required for the water to be pumped, treated against corrosion , and equipped with detachable wear rings. The bowls shall be joined by flanges or by tie rods.

The shaft main guide bearings located in the suction and delivery end housings of the pump shall utilize a leaded-bronze material, and shall be provided with protection guards to prevent ingress of sand and grit. Pump bowl guide bearings shall utilize either leaded bronze or other approved abrasion resistant material. All pump bearings shall be lubricated by the water to be pumped. The pump delivery end housing shall incorporate a thrust washer of suitable material at the shaft end to absorb upthrusts that occurs during pump starting. The pump shall incorporate a mushroom type delivery check valve to prevent reverse rotation of the shaft from back flow of water through the pump. The pumps shall be provided with a flanged discharge connection suitable for operating against the pump closed valve head or 16 bar whichever is the greater. The shaft coupling connecting the pump and driving motor shall be of stainless steel material accurately machined and keyed to ensure precise shaft engagement and alignment. A strainer of suitable corrosion and abrasion resistant material, designed to guard against entry of foreign matter but permitting unrestricted flow of water into the pump, shall be provided on the pump suction housing.

Protection against the effect of sand shall provided by renewable wear rings (made from a hard smooth flexible material such as polymethane) mounted at the seating of the impellers and the passages of the shaft.

The pump shall be designed to pump water having a sand content of up to $80g/m^3$.

A centralize shall be fitted to every pump to ensure central alignment of the pumping and motor in the borehole casing.

Electro-submersible motors shall be ‘wet’ squirrel cage rotor induction type designed to operate continuously under submerged conditions and shall, where appropriate, comply with the requirements of IEC publication 34. They shall have operating speeds not in excess of 3000 rpm.

The motors shall have an efficiency of at least 80% when operating between 75% and 100% of nominal power output and shall operate at a power factor of at least 0.8 in the same output range.

Motors shall be continuously rated at least 20% above the maximum power absorbed by the pump within the specified operating range. Motors shall be designed to allow three consecutive starts from cold and three starts in any one hour when hot.

The motor housing shall be constructed from close grained cast iron, cast steel or fabricated steel as appropriate, and shall be designed for easy dismantling and re-assembly to facilitate replacement of motor guide and thrust bearings.

The motor windings shall be insulated with an approved heat resistant material of high insulation resistance and impervious to water. All connections on the motor windings

shall be made watertight. The temperature rise of motor windings shall be limited to 45ºC above ambient water temperature.

The motor shall be equipped, in factory with several PTC or Pt100 thermoprobes, 2 minimum, connected to a multifunction protection relay and a pre-selection digital thermometer which cuts off the operation current of the starter when the threshold temperature is reached. The temperature setting of this device shall depend upon the type of the probe determined by the manufacturer according to the insulation class of the motor.

The motor shaft shall be machined from high tensile stainless steel of sufficient diameter to prevent distortion from the dynamic and electro-magnetic stresses imposed on it. Critical shaft speed shall be well above the maximum running speed.

The motor shall be provided with a heavy duty multi-pad thrust bearing at the base of the motor to absorb the shaft down thrust developed by the pump. The bearing design shall incorporate tilting thrust pads with replaceable segments arranged to self adjust according to the thrust load. The thrust disc shall be of a suitable segments carbon based or similar approved material.

The thrust bearing design shall also be suitable for reverse rotation of the shaft in the event of backflow of water through the pump.

Motor guide bearings shall utilize either leaded bronze, copper impregnated carbon or similar approved material. Rubber, nylon, Tufnell and similar materials will not be accepted for the motor guide bearings.

Motor guide and thrust bearings shall be lubricated by the motor coolant water which shall be effectively isolated from the water to be pumped. A compensating device shall be incorporated in the motor design to allow for expansion of the coolant on rising temperature.

V-A.15-20 Borehole Pumps Rising Column

Steel borehole rising column shall be provided in section lengths not exceeding 3 metres with flanged joints or screwed couplings. The rising column shall be sufficiently flexible to allow for small deviations in borehole verticality. All nuts, bolts and washers shall be of stainless steel. Rising column flanges shall incorporate a recess to accommodate and protect the motor power and control cables, water level dip tubing, etc. Cables and tubing shall be securely fixed to the rising column by straps or bands at approximately 2 meter intervals.

The rising column shall be sufficient to take the stresses generated by the hanging weight of the pump, motor and rising column, the stresses produced by the water pressure

together with any dynamic stresses which may occur under any circumstances including valve closure. Jointing materials shall be selected with care and shall accommodate the extension of bolts due to the expected weight and surge or closed valve pressures generated in the pipeline.

The rising column shall be protected internally and externally against corrosion by a non toxic epoxy resin coating suitable for use with potable water.

V-A.15-21 Borehole Pumps Headworks

A fabricated steel discharge head piece shall be provided at the top of the borehole to support the complete rising column and electro-submersible pumpset assembly, and shall be complete with lifting eye bolts. The discharge head piece shall comprise a heavy duty sealing plate arranged for bolting to the borehole outer casing flange, and a 90º discharge bend arranged for flanged connection to both rising column and horizontal surface pipework. Lifting eyes shall be provided in the sealing plate. A

flange shall be provided and welded by the Contractor to the top of the borehole outer casing. The flange shall be suitably drilled to accommodate the discharge head piece sealing plate bolts. Holes shall be provided in the sealing plate to accommodate an air vent pipe, motor and control cables, water level dip tubing, etc. and shall include adequate sealing arrangements to protect against borehole contamination. A 25mm diameter screwed removable plug shall be provided over the dip tubing for water level measurement with electrical contact tape. A stainless steel air vent pipe shall be fitted to the discharge head sealing plate, terminating in an insect proof screen and arranged to prevent entry of rain or surface water.

V-A.15-22 Vertical Turbine Pumpsets

The pumps shall be of the vertical line shaft type. The discharge head shall be bolted onto a substantial steel bedplate or frame which shall in turn be bolted to the pump room floor. The discharge head shall have a flanged discharge. The suction casing and impeller bowls shall be of cast iron. Replaceable seal rings shall be fitted on the impeller suction side if required to maintain pump hydraulic efficiency.

The impeller shall be bronze or other material to suit the characteristics of the water to be pumped. The pump shaft shall be of stainless steel supported by bearings above and below each stage. Protection shall be given against the effects of entrained solids in the water being pumped intermediate bearings shall be lubricated by the liquid being pumped.

The line shaft shall be machined and ground carbon steel supplied in lengths not exceeding 3.0m, with screwed couplings. The line shaft bearings shall be spider type to locate the shaft in the tube and may also double up as line shaft tube couplers. Lubrication shall be provided to the bearings.

The pump suction shall be of at least equal diameter to the pump and shall be fitted with a suction strainer.

Means shall be provided of adjusting the pump shaft tension and position.

V-A.15-23 Chemical Metering and Dosing Pumps

Chemical dosing shall be by means of electrically driven metering pumps unless otherwise particularly specified.

Metering pumps shall be of the plunger or progressive cavity type.

The effective range of the metering pumps shall be between zero and maximum with an overall repeatable accuracy within ±3%. Output shall be adjustable through a stepless variable stroke mechanism in the case of plunger pumps and variable speed motor or gearbox in the case of progressive cavity pumps.

The metering pumps shall be manually adjusted, and shall be calibrated to allow setting at the required dosage. Dose adjustment shall be possible whilst the units are in operation. Accurate dosing shall be maintained down to 10% of the maximum dosing rate.

The Contractor shall consider the liquid to be pumped and select the materials of construction so as to avoid corrosion. Mechanical glands are generally undesirable but where unavoidable, shall be to the approval of the Engineer.

For metering pumps of the plunger type the materials in contact with the liquid shall be polypropylene, stainless steel grade 316, uPVC or PTFE. Plungers shall be a high-alumina ceramic or stainless steel, grade 316.

Metering pumps shall be mounted on bed plates which shall be protected from gland drip. The pumps shall be driven by close coupled motors with reduction gears and have mechanisms housed in a totally enclosed oil bath.

At least one standby pump, fully connected into the chemical dosing system, shall be provided for each chemical, with local manual selection of duty and standby units. When pump duty change-over is effected the appropriate suction and delivery isolating valves shall be manually operated.

Stators and rotors for progressive cavity pumps shall be of materials selected having regard to the liquids being pumped.

The design and location of the metering pumps shall be such as to facilitate easy dismantling for the removal of any foreign matter.

Flushing facilities shall be provided for all chemical pipework at the inlet and outlet of each metering pump, together with drip trays to contain any spillage or leakage and piped to the nearest drain point. Provision shall be made for priming the systems to eliminate any air.

Each chemical dosing pump shall be provided with suitable isolating valves, an inter-connecting manifold system and, where necessary, loading valves. A calibrated glass container shall be provided connected into the suction manifold of each chemical pump so that its output can be checked.

Calibration curves shall be provided by the Contractor for all chemical dosing pumps.

V-A-16 Compressors/Blowers

V-A.16-1 Air Compressor

The compressor shall be an air cooled type capable of oil. Air delivery at the volume and pressures specified when directly or indirectly driven by an electric motor or diesel engine.

The compressor performance shall be in accordance with BS 1571 for the site condition and duty cycle specified and shall include the following components:

- Suction air filter/silencer
- Solenoid operated unloader valve
- Pressure relief valve
- Non-return valve
- Isolating valve
- Low oil pressure switch (if pressure lubricated)

Where necessary, depending on load factor, the compressor shall include cylinder jacket and after cooler facilities for cooling the delivered air, the aftercooler having a suitable pressure relief valve and automatic drain valve.

V-A.16-2 Air Receiver

The compressor shall deliver air into an air receiver manufactured in accordance with BS 5169 Class III Grade E or F, to accommodate the specified design pressure and internal volume.

The receiver shall incorporate the following items:

- One safety relief valve.
- One automatic drain valve.
- One pressure gauge (0 - bar).
- Pressure and temperature switches to suit the control.
- Inspection access to permit internal examination of the receiver.
- Lifting facilities as determined by the receiver weight.

The receivers shall preferably be located in low ambient temperature areas to minimize condensation and the inlet and outlet pipe connections shall be arranged to promote air circulation.

V-A.16-3 Separators

The air distribution main shall include a separator designed to remove suspended moisture in the air main.

V-A.16-4 Compressed Air Filters

The air supply shall incorporate filters of the disposable element type as near as possible to the point of use.

Filtration shall be carried out using two filters in series, the first filter graded for course filtration and the second for fine filtration as defined in the Specific Requirements.

V-A.16-5 Drain Traps/Strainers

Automatic drain traps shall be provided for air receivers, filters and separators. Strainers shall be provided for protection of the drain traps. Ball traps shall have cast iron bodies with stainless steel internal parts (Spirax Sarco or equal).

V-A.16-6 Air Pressure Control

The compressor shall be arranged to maintain the air pressure in the system within the specified limits by means of pressure switches in conjunction with unloader valves and timers to prevent prolonged off-load running.

The frequency of starting and stopping shall be within the limitations of the drive arrangement.

Where two compressors are operated on a duty/standby basis, the duty compressor shall operate whenever the low pressure switch closes and shall cease operation when the high pressure switch opens. Should the pressure fall to the standby low pressure, the standby compressor shall operate in conjunction with the duty compressor and shall similarly cease operation when the high pressure switch opens.

The circuits for the compressor motor starters shall be completely separate. Either unit shall be capable of duty or standby operation and periodically their modes will be reversed.

The blower shall discharge continuously the specified free air delivery at specified suction and delivery pressures.

The blower shall be of the centrifugal or positive displacement rotary type with cast iron casings capable of delivering oil-free air. The blower shall be fitted with mechanical seals and incorporate a mechanical oil lubrication system, including an oil flow indicator, level indicator, pressure gauge, filling and drain plugs.

The design of the blowers is to be such that the noise level is to be kept to a minimum.

The impellers shall each be equipped with heavy-duty spherical roller bearings at each end. Gear end bearings shall be axially located on the inner and outer races to control thrust and maintain factory set clearances at all times.

The two timing gears shall be accurately machined to position the impellers in the impeller case and shall be secured to the shafts by locking kits. Gears shall be enclosed in an oil-tight housing.

The shaft sealing arrangement shall comprise a garter spring viton lip seal and a piston ring seal with an intermediate space vented to atmosphere.

Gears and gear end bearings shall be lubricated by a splash oiling system from oil maintained in the gear housing. Drive end bearings shall be grease lubricated or lubricated by a splash oiling system from oil maintained in the drive cover, depending upon gear size.

Each blower is to be direct driven through a flexible coupling, or indirectly via `V' belts, by means of an electric motor, the complete assembly being mounted on a cast iron combination base plate. Both driver and driven units are to be dowelled or otherwise positively located to the base plate and substantial guards provided over all moving parts.

All covers and flanges associated with spigotted joints should be provided with easing screws if possible.

V-A.16-7 Blower Accessories

Each blower shall include a tachometer, an adjustable weight operated lever type air relief valve, delivery pressure and suction gauges each with isolating cocks mounted on a panel secured to the blower. An automatic unloader vented to outside atmosphere or an approved by-pass system is also to be included if this will assist in starting.

The air relief valve is to be of double flanged cast iron construction with gunmetal trim. The adjustable weight shall have provision for locking to prevent any unauthorized interference.

Bosses shall be provided on each blower discharge pipe, upstream of the non-return valves, suitably tapped for connection by capillary tubing to pressure switches.

V-A.16-8 Blower Filters

The filters shall be capable of handling the designed throughput of air with the minimum of pressure drop whilst excluding 99.7% of all particles down to 2 microns.

The filters shall be of the two stage type comprising a hand operated roller mounted first stage roll type element and a disposable cartridge type second stage having access from one side only. The first stage unit is to be mounted in a galvanized sheet steel case with easily removable covers, the roller handle being conveniently positioned for easy adjustment of the roll. The second stage unit is to be mounted in a galvanized sheet steel case and the units connected by a transition piece, a further transition piece being arranged between the second stage and the silencer. Connections with isolation taps are to be provided on both sides of each stage and suitable manometers fitted to allow for measurement of the differential pressure.

Each unit shall be supported from the floor on substantial steel frames with welded plate feet.

V-A.16-9 Air Silencers

Single inlet and outlet silencers shall be included for the blowers and manufactured of sheet steel, comprising a perforated inner tube and an outer galvanized casing, the space between being filled with a sound absorbing material. A flange is to be provided at each end, and all necessary supports extending to floor level are to be included. The silencers are to be designed for the minimum pressure drop.

V-A-17 Surge Suppression Equipment

Surge vessels and associated equipment for suppression of surge in pumping systems shall include the following:

a. Surge pressure vessel designed and constructed to BS 5500, constructed category 1, 2 or 3, post weld heat treated and with a corrosion allowance of 1mm. The vessel shall be cylindrical, carbon steel, fusion welded with domed ends and mounted either vertically or horizontally on steel supports. The vessel shall be provided completely including the following fittings:

   - McNeil type access manhole with opening not less than 450 mm x 410 mm;
   - Water inlet/outlet branch flanged to BS 4504 Table 16 or 25 as necessary;
   - 100 mm dia. drain branch with gunmetal valve and handwheel with drain pipework discharging to drainage channel;
   - Spring loaded gunmetal safety valve;
   - 150 mm dia. pressure gauge complete with gunmetal isolating cock;
   - Water level sight glass with isolating and blowout prevention valves;

- Air inlet fitting incorporating an air release valve and isolating and non-return valves;
- Three stainless steel water level control electrodes of appropriate length, complete with electrode holders, spacers and brackets;
- Access ladder;
- Lifting lugs;
- Nameplate giving vessel details.

b. One or more air compressors with standby facilities . Each compressor shall be capable of charging the pressure vessel from full of water in approximately 30 minutes. The compressors shall be air cooled, electrically driven and complete with baseplates.

The compressors are required to deliver completely oil-free air but may be of the air lubricated type with two stage carbon air delivery filters providing complete removal of moisture and oil vapor. Each compressor shall be provided with the following fittings:

- Outlet pressure gauge
- Pressure relief valve
- Suction filter and silencer
- Automatic unloading valve for a no-load start under all conditions
- Non-return valve
- Protective guard between motor and compressor.

c. Control equipment to provide fully automatic control of the selected duty compressor from the water level electrodes in the surge vessel. A time delay shall be incorporated to prevent operation of the compressor during water level changes under surge conditions and a push button feature shall be provided for manual test of the system. The control equipment shall be housed in a wall mounted panel fabricated from mild steel to form a rigid box construction of neat appearance providing an enclosure to IP54. The enclosure door shall be hinged with a rotating handle and positive closing action. The equipment shall include:

- A three pole isolating switch, with operating handle interlocked with the enclosure door.
- A water level control module
- A 0 to 30 minutes adjustable timer
- A non-latching motor test push-button

d. Ductile iron flanged inlet/outlet pipework between a flanged tee on the pumping station or wellhead delivery pipework and the surge vessel.

The pipework shall include an isolating valve with gearing and handwheel and all necessary bends and fittings.

e. Small diameter GMS pipework between the air compressors and the surge vessel. The pipework shall be suitably coated and wrapped.

f. All cabling:

- Between the switchboard and the control panel
- Between the control panel and the compressors
- Between the control panel and the level electrodes on the surge vessel
- Earthing of all equipment.

For small installations a vessel with a flexible membrane and hand air pump may be used.

V-A-18 Cranes and Hoists

Cranes and hoists shall be of standard proven design in accordance with BS 466, rated for lifting the specified working loads, utilization and service conditions and shall be suitable for operation from the runway beams provided. Motions shall be motorized as specified with dual speed hoisting facility and controlled from a pendant push button unit via a crane control panel mounted on the gantry.

All operations, whether manual or electric, shall be controlled or performed from motor room floor level unless otherwise specified.

The lifting assembly shall be rated for the highest lift that could occur during installation and maintenance operations.

The crane shall consist of a gantry or jib, crab and hoist assembly, ropes, block and hook together with the necessary running rails and all electrical supply requirements.

Chains used for lifting or travel shall be alloy steel and corrosion protected by an electro-deposited, zinc coated finish after manufacture. They shall not be hot-dip galvanized.

Jibs or gantries shall be of plate or box girder design and securely attached to end mountings or carriages.

End carriages for gantries shall be fabricated from rolled steel plates and have two, double-flanged, cast steel wheels to match the track rails. Where rails are supplied and installed under this contract, they shall be adequately supported throughout their length to carry all the dynamic and static loads imposed by the crane duty.

Crab assemblies shall be mounted on four flanged cast steel wheels to suit the jib runway beam or cross-travel rails fixed to the main crane gantry.

Each travel range shall be the maximum permitted by the building and runway constraints. Where applicable the extent of each travel motion shall be limited by electrical limit switches with mechanical end stops secured to the travel rails beyond the electrical limit switch positions, to prevent overrun and building damage from swinging loads. Mechanical end stops shall also be provided where travel is by manual operation.

In the case of electric motor driven travel two travel speeds shall be provided. The fast speed shall not exceed 16m/min and the slow speed not exceed 4m/min. These drives shall always start at the lower speed and incorporate smooth acceleration and deceleration controls.

V-A.18-1 Hoist

The hoist unit on traveling beams shall be mounted to provide the highest possible lifting facility whilst maintaining adequate clearance between the crab/hoist assembly and the building structure and fittings.

Hoist units fitted to single runway beams, fixed or jib mounted, shall be of the self-suspension type mounted on a single rigid trolley suitable for manual geared travel along the runway beam. Two end stops shall be provided on the beam suitable for the trolley provided. The trolley shall have ball or roller bearings grease packed for life.

The hook shall be fitted with a swivel and a safety catch and be capable of touching the floor and providing a minimum lifting height as specified.

In the case of electrically operated hoists the normal hoist speed shall be approximately 4 meters/min and the creep speed shall be approximately 600mm/min or nearest standards. An overload device and overwind limit shall be included to prevent dangerous overloads. Raise and lower limit switches shall be provided at the maximum and minimum lift positions. Instantaneous fail safe braking in the event of power failure shall be provided.

Where operation is by electric motor a power supply shall be provided under the contract. Power shall be taken from a feed in the main distribution panel forming part of the works and a wall mounted

fused isolator shall be provided at a suitable location approximately 1.5 m above floor level alongside the lifting installation.

Power transmission to the moving installation shell be by pick up shoe running along the underside of shrouded rails, suspended concertina cable running on slides or a rail or a cable from a self winding cable reeling drum . In the latter case the tension in the cable shell be controlled and supports provided to prevent the cable drooping more than one meter below the crane rail (s).

V-A.18-2 Testing

All lifting equipment shall be tested at the manufacturer's works and on site. Tests on site shall comprise a full load test, including, where applicable, deflection checks on beams. Where the contractor wishes to use lifting equipment forming part of the permanent works for installation purposes he shall have the equipment tested and be in possession of a valid test certificate before using the equipment. All equipment must be tested or retested within one month of handing over to the Employer. Test certificates shall be provided in triplicate . The contractor shall be responsible at his own cost for the provision of all weights, slings and other equipment required for testing.

V-A.18-3 Rating Plates

The SWL shall be clearly marked on the rating plate and shall be legible from the plant working level.

V-A.18-4 Paint Finish

The finish color shall be a full gloss Yellow Color No. 356 to BS381 or equivalent reference 08 E 51 to BS 4800.

V-A.18-5 Crane Access

Where clearances permit, provision for safe access for maintenance shall be provided in accordance with BS 466 and shall include a walkway across the span having a height clearance of 2m and be fitted with double-tiered handrails and toe boards.

V-A-19 Gas Chlorination

V-A.19-1 General

Gas chlorination equipment for installation at pumping stations, reservoirs and water treatment works and other locations on the system generally come under one of two categories.

a. Gas chlorination feeding into pressurized and gravity lines at locations where an electricity supply is available.

b. Gas chlorination at those locations, such as water catchment works, outlets from reservoirs etc where there is no electricity supply.

This specification covers both categories.

The contractor is responsible for the safe design, provision and installation of the chlorination dosing system and associated safety equipment. The safety equipment required varies from site to site depending on site location, quantity of chlorine stored or dosed and type of equipment supplied. The contractor shall access the requirements of each installation with respects to the following points:

- ventilation system
- leakage detectors
- Audio and / or visual alarms
- automatic shut down systems
- personal protection equipment

- procedures and training.

The equipment called for in this section are nominal requirements.

The scope of works for the provision of chlorination equipment includes, as appropriate to the particular category above:

1. Supply and transport to site of all equipment including chlorinators, centrifugal booster pumps, chlorine bottles, and all other material and equipment necessary for the installation.
2. Installation of chlorination equipment and fittings, pumping equipment, metering, pipework and valves, control and protection equipment to form a safe, effective and fully operational installation.
3. All necessary civil and building works.
4. Testing, commissioning, training and putting into service full equipment.

V-A.19-2 Vacuum Chlorination of Pressurized Water System

This system is applicable at pumping stations, water catchment works etc. where the water to be treated is under pressure and electricity is available.

A centrifugal booster pump shall be provided to supply pressurized water to the chlorinators.

Where specified the rate of chlorine injection shall be controlled by flow metering and proportional to the water flow rate.

V-A.19-3 Equipment Characteristics

Injection of chlorinated solution shall be by vacuum type chlorinator, the vacuum being achieved by pressurized water and ejector.

The chlorinator may be either wall mounted or mounted directly on the head of the chlorine bottle. It shall include:

- Pressure reducing valve
- Flow control valve
- Injection device
- Pressure relief valve to act in case of surge pressure of chlorine or loss of suction.
- Pressure gauges up and downstream of the booster pump.
- Non return valve downstream of the chlorinator.

The injection service pressure (bar) and chlorinator capacity shall be calculated by the Contractor and designed from information in the particular specification for each installation.

The contractor shall supply all necessary equipment and fittings for operation, control and maintenance in accordance with the following list.

The list is indicative and by no means restrictive.

V-A.19-4 Water Circuit

a. Motor Driven Pumpset

b. An electric motor driven pumpset shall be provided to achieve the discharge rate and pressure for chlorinator operation.

c. The booster pump discharge rate and pressure shall be as the chlorination equipment manufacturers specification. The pump assembly shall comprise a three phase 380V electric

motor with a minimum protection class IP55 and maximum speed of 3000 rpm., and a centrifugal pump mounted on a common base plate.

d. Non return valve downstream of the pump.

e. PVC or bronze valves (Upstream and downstream of the pump)

f. PVC or bronze control valve downstream of the pump.

g. Bronze strainer (1mm) upstream and downstream of the pump.

h. 10 or 25 bar pressure gauges as appropriate upstream and downstream of the pump.

i. Piping, treated against or resistant to corrosion.

V-A.19-5 Chlorine Circuits

Chlorine resistant non-return valve.

a. Anti-siphon system

b. Chlorine resistant chlorinated solution injection device.

c. Chlorine resistant pipework for chlorinated solution injection.

d. Chlorine resistant pressure relief piping for release of gaseous chlorine in the event of over pressure, to a maximum length of 8m.

e. Piping between chlorinator and injection device, complete with fittings, all of chlorine resistant material.

f. Non return valve.

V-A.19-6 Chlorination of Pressurized and Gravity Systems in the Absence of Electric Power Supply

This system is for use where there is no power supply available, for example supply and delivery lines at reservoirs, catchment areas and headworks.

The chlorination process shall cease immediately in the event of lack of water.

V-A.19-7 Chlorination under low pressure

Use of low pressure chlorinators shall only be used where use of vacuum types is impossible due to insufficient line pressure.

The chlorinator shall be either wall mounted or directly assembled to a gaseous chlorine bottle, the latter providing pressure for operation of the chlorinator. A chlorine resistant piping connection shall link the chlorinator to a diffuser. In the case of a reservoir a spring loaded check valve shall be installed at the point of chlorine injection.

A nozzle injector rather than a diffuser shall be used for injection into a pipeline.

Where injection is into the pipeline pressure in the line shall always be more than 0.1 bar (g) and shall not exceed 0.7 bar (g). Partial vacuum in the pipe must be prevented.

In the case of a reservoir the level of water in the reservoir shall always be at least 1m above the diffuser.

The size of the piping between the chlorinator and the injection point will be a function of both dose rate and distance between the points.

V-A.19-8 Chlorination by Vacuum Chlorinator

Chlorination under vacuum only applies to reservoir gravity supply lines, the latter associated with a minimum hydraulic pressure of 0.5 bar. A hydro ejector shall achieve the required hydraulic pressure

for injection provided a pressure drop is produced downstream of the hydro ejector feed point (By a valve or diaphragm).

The contractor shall optimize the locations of feed and injection points in such a way as to achieve a minimum hydraulic pressure of 0.5 bar upstream of the hydro ejector. The capacity of the chlorinator shall not exceed 200 gr/hr at a hydraulic pressure of 0.5 bar or 300 gr/hr at a pressure of 1 bar.

Chlorination shall cease immediately in the event of lack of water in the line.

V-A.19-9 Chlorination Dosing Pump

Disinfection shall be achieved by injection of chlorinated lime or sodium chlorite (Javel water), by means of a dosing pump proportionally to the rate of flow of water. The chlorinated solution shall be stored in corrosion proof tanks.

The operation of the dosing pump shall be controlled by a flow meter equipped with a pulse transmitter. A control system receiving the transmitted pulses, shall regulate the dosage of chlorinated solution.

Supply of power shall be by:

A low leakage, self discharge, maintenance free battery with no water addition required.

A battery charging solar panel complete with either a charge regulator or an electronically controlled battery charger housed in a class IP55 box equipped with LED indicator.

The contractor shall supply and install such other equipment as may be necessary for the safe operation of the system.

V-A-20 Control Systems based on flow rate of water

V-A.20-1 General

The control system shall comprise a chlorine injection regulating system. It shall include:

a. A chlorinator for use with pressurized water systems.

b. A water flow meter with an output signal proportional to the rate of flow to be treated.

c. A motorized chlorine flow control valve with feedback signal to the control system, the signal to be proportioned to the chlorine injection rate.

d. A feed back control system with signal comparator. In the case of signal discrepancy the control valve servomotor shall be actuated to adjust the injected dose of chlorine.

e. The injection nozzle and/or hydro ejector.

f. If specified the facility to receive a signal from a residual chlorine analyzer which will adjust the chlorine/water ratio.

V-A.20-2 Requirements of the above Control Systems

a. Chlorine Flow Control Valve

The motorized control valve shall be functionally compatible with the chlorinator. It shall achieve automatic control of the chlorination process as a function of the rate of flow of water to be treated.

The supply voltage shall be 220V, 50 Hz with a two pole circuit breaker equipped with adjustable thermal trip.

The valve capacity shall not exceed 10 kg (gaseous chlorine)/hr. It shall receive and transmit a 4-20 mA signal to the chlorinator. The valve can either be incorporated in the chlorinator or installed separately in the system.

b. Water Meter

The water flow meter which may be of the turbine, magnetic flow, diaphragm or ultrasonic type, shall control the operation of the motorized control valve. It shall have the following characteristics:

- Be suitable for fluids with up to 80 mg/l solids particle content. It shall be designed for a range of water velocities from 0.5 to 3.0 m/s and shall transmit a 4-20 mA signal.
- Operate on a supply voltage of 220V or 110V - 50 Hz.
- Be equipped with a rate of flow indicator.

V-A-21 Control Systems Based on Residual Chlorine Metering

V-A.21-1 General

The system shall include:

a. A vacuum chlorinator injecting into a pressurized water system.

b. Chlorine injector flow control valve actuated by a converter to a residual chlorine analyzer with signal transmission to the control valve of a signal proportional to residual chlorine concentration in the treated water.

The residual chlorine analyzer shall be equipped with an electronic transmitter, and shall be one of two types.

Type "A" (with reagent)

The residual chlorine analyzer shall be of the amperometric type for measurement of residual chlorine in water.

It shall include:

1. Measuring cell.
2. Suitable reagent to allow measurement of the concentration of total and/or free residual chlorine.
3. Amplifying circuit and converter with 4-20 mA output signal. The above to be incorporated in the analyzer bar.
4. Zero point and scale adjustment features with automatic temperature compensation feature, to compensate for errors due to temperature fluctuation of the sample.
5. Direct reading indicator.
6. All components to be installed in a corrosion resistant box. The characteristics shall include:
    - Scale range 0-0.5, 0-2.0 mg/l
    - Water sample temperature range 0-50oC.
    - Output signal 4-20 mA
    - Supply voltage 220v - 50 Hz with 2 pole circuit breaker with adjustable thermal trip.
    - Indicator: located on front of analyzer.
        - Direct reading in mg/l
        - Accuracy ±2% of scale range.

Type "B" (Dry Type)

The analyzer shall consist of a potentiometric cell fitted with three metallic electrodes that shall generate a current directly proportional to the concentration of free residual chlorine.

It shall be equipped with a potentiometric amplifier and a converter to transform the current to a 4-20 mA signal.

The circuitry shall include a zero point and scale adjustment feature as well as automatic temperature compensation feature (Thermistor) in order to compensate for errors due to temperature fluctuations of the sample.

It shall have a direct reading indicator and be installed in a corrosion resistant box.

The characteristics shall include:

- Scale ranges 0-0.5, 0-2 mg/l
- Water sample temperature range 0-50oC
- Output signal 4-20 mA
- Supply voltage: 220V - 50 Hz with 2 pole thermal magnetic circuit breaker.
- Indicator: located on front of analyser
  - Direct reading in mg/l
  - Accuracy ±2% of scale range.

V-A-22 Auxiliary Equipment for Chlorination and Storage

V-A.22-1 General

Where electric power is available the chlorination room shall be equipped with an extractor fan at low level with high level air inlet. The fan shall give twenty air changes per hour and shall have a control switch located inside and outside the building. A sign shall be fixed to the outside of the door "Danger, Toxic Gas - Access for authorized personnel only", in English and Arabic.

There shall be available at each chlorination building 2 No gas masks consisting of an integral mouth piece and wide view visual piece covering the entire face, complete with flexible breathing tube and filter cartridge with hipstrops.

2 No additional filter cartridges shall be supplied with each mask.

The filter shall be effective in neutralizing gaseous chlorine.

A shower shall be fitted to the wall immediately outside the chlorination room for emergency use. It shall have a chain operated valve.

The masks shall be kept in a dedicated wall mounted cupboard in the control room or attendants room. The cupboard door shall have affixed to it a label stating "Chlorine gas masks. Fit new cartridge before use."

V-A.22-2 Chlorine Bottles

2 No or more chlorine bottles shall be supplied with each chlorinator. They shall be 50 kg capacity each unless specified otherwise.

Each bottle shall be equipped with:

- An isolating valve, which shall be provided with a protective cap during transport.
- Where specifically called for, an automatic chlorine supply change over to a standby bottle on depletion of the duty bottle. The system shall be wall mounted and shall be functionally compatible with the chlorinators. It shall function on partial vacuum and shall be complete with all accessories and fittings.
- A bottle rack and chain support.

- Where specifically called for, a permanent weighing device shall be provided beneath the bottle in service to continuously monitor the rate of chlorine consumption.

The chlorine bottle storage area / room shall be sized and equipped to facilitate a safe environment for the bottles storage, handling and changing.

V-A.22-3 Chlorine Detector

Where specifically called for or deemed necessary, gaseous chlorine detector units shall be fitted. The gas leak detector shall be used in conjunction with an alarm which shall be actuated if the gas concentration arises above 1 ppm or 3 mg gas/cu.m of air.

The detector may be one of two types:

Type A (Dry Cell)

The gas detector shall consist of an independent tank and detection cell located outside the tank. The tank capacity shall be sufficient to give 6 months operation. The detection cell (sensibility 1mg/cu.m) shall be connected to an electronic measuring device located in a wall mounted box. In the presence of an oxidizing gas the detection cell shall generate a current proportional to the gas concentration.

The box shall have an electronic indicating device and shall give continuous monitoring.

When gas concentration reaches its maximum permissible limit the detector shall activate visual and acoustic alarms, and shall trigger the operation of a remote alarm, where fitted, the operation of the extractor fan and closure of the supply line valves.

A test push button shall be provided to allow the operation to be checked.

Type B (Wet Cell)

The detector shall have live electrodes under constant supply voltage, immersed in an electrolyte that shall conduct current in the presence of an oxidizing gas. The generated current shall be amplified and converted to a signal.

The box shall have an electronic indicating device and shall give continuous monitoring.

When gas concentration reaches its maximum permissible limit the detector shall activate visual and acoustic alarms, and shall trigger the operation of a remote alarm, where fitted, the operation of the extractor fan and closure of the supply line valves.

A test push button shall be provided to allow the operation to be checked.

V-A-23 Leak Detection, Residual, Free Residual and Total Residual Measurement

A bottle of liquid ammonia for chlorine vapor leak detection purposes and a measuring kit for quick determination of the concentration of the following shall be provided with every chlorination equipment installation.

- Free residual chlorine
- Residual chlorine
- Total residual chlorine

Details of the equipment to be provided, which shall include all auxiliaries, shall be provided with the tender.

V-A-24 Installation of Equipment

The location of the chlorine bottles in the store shall be away from direct sunlight at all times. During transportation of bottles the contractor shall ensure that gas bottles are not overturned and that safe handling procedures are adopted at all times.

Gaseous chlorine piping connections between system components shall follow the shortest and most direct route possible and shall be laid to falls.

Water and other piping shall not be laid immediately alongside gaseous chlorine piping in order to prevent cooling and condensation.

Only grease or other lubricant as recommended by the equipment manufacturer shall be applied to all removable fittings.

Where the chlorinator is installed remote from the gas bottle the distance apart shall not exceed 10 meters.

The chlorinator vapor vent pipe shall be extended to outside the building away from inhabitated areas. The vent pipe outlet shall be covered with a mosquito net.

Chlorination equipment piping shall be secured to the wall by brackets with a minimum clearance of 100mm off the walls for painting and maintenance purposes.

V-A-25 System Start-up

The procedure for putting chlorination equipment into service shall include:

- A bacteriological and physico-chemical analysis of the water to be disinfected.
- Determination of the chlorine demand of the water to be disinfected based on break point method.
- Adjustment of the chlorinator capacity to achieve, after 30 mins of chlorine to water contact a residual concentration of 0.5 mg/l. A check shall be made by measurement of the concentration of free chlorine in water at a pre-determined location in the water distribution system.

In the case of a chlorinator controlled by an automatic residual chlorine measuring device, the indicated concentration shall be checked against the result of an analysis of residual chlorine in the water sample.

V-A-26 Disinfection Control

Following start up of the chlorination system the contractor shall take five samples of disinfected water at five different locations situated at representative distances from the chlorination point so as to achieve effective control of the quality of disinfected water. The following tests shall be undertaken.

- Measurement of free chlorine (Type b1)
- Measurement of free chlorine in water.

V-A-27 Pressure Testing of System

Prior to system start up all chlorination systems shall be pressure tested for leaks.

- The system shall be tested with nitrogen or dry air at a test pressure 50% higher than the service pressure. Soapy water shall be applied to all joints and connections to facilitates detection of leaks.
- The system shall be tested with chlorine. A rag soaked in liquid ammonia shall be brought to the vicinity of all potential leak points, leaks being evidenced by production of white ammonium chloride fumes. In the event of a leak, prior to effecting repairs, gas bottles shall be isolated and the lines drained through the dosing pumps.

IMPORTANT Procedure for Pressure Tests

1. Open all valves one turn except gas bottle valves.
2. Open gas bottle valves to achieve a system pressure of 1-2 kg/cm^2 and close them again.
3. Search for leaks with an ammonia soaked rag.

4. In the event of a leak drain the lines with the dosing pumps and repair the leak.
5. Open gas bottle valves to achieve maximum system pressure.
6. Repeat 4 and 5 above.
7. When system is leak free open gas bottle valves one turn.

V-A-28 Tests on Completion

The tests on completion shall include the following:

- Injection rate
- Injection pressure
- Absence of leaks
- Injected concentrations
- Compliance with specification
- Safety criteria and equipment
- Such other tests as the Engineer may determine.

V-A-29 Site Procedures and Training

V-A.29-1 General

Training should be carried out with emphasis being given to safety precautions and methods of dealing with emergencies. Particular attention should be given to the following aspects:

1. the hazards and characteristics of the material;
2. safe methods of plant operation, including handling of the connection to supply systems;
3. methods of maintenance;
4. special operations; for example, plant shut down and start-up, methods of isolation and preparation of equipment for periodic maintenance and inspection;
5. the location and operation of emergency shut-off valves;
6. the procedures to be followed if releases occur;
7. training in the use of all personal protective equipment supplied.

V-A.29-2 Operating Instructions

The operating instructions should cover each process operation. Written operating instructions are required, in English and Arabic, for all routine and emergency operations, ranging from guide cards for simple operations to complete manuals.

Copies of the instructions, which should include a flowsheet and indicate valves to be closed in an emergency, should be available in the working area for operators.

V-A.29-3 Emergency Arrangements

The emergency procedure should include how gas releases may be dealt with safely by site personnel. The procedure should cover various degrees of emergency and should be either supplied in written form or made available to employees so that they know the steps they are required to take. This procedure should include first aid and evacuation arrangements

V-A-30 Valves And Penstocks

V-A.30-1 Types and Operating Conditions,

Valves shall be designed to meet the operational and environmental conditions specified for the types indicated in the specific valve schedule.

The closure rates of all valves shall be designed to prevent the effects of surge. Where necessary, valves with a varying closure rate shall be used.

Valve flanges or couplings shall be as specified in the valve schedule and match those specified for the pipework installation.

V-A.30-2 Identification

Each valve shall be identified by a unique reference as approved which shall identify the medium/plant controlled and be numbered in a logical sequence.

The reference shall be either engraved on a 3mm thick laminated white/black/white traffolyte disc or stamped on a 1.0mm (19g) thick brass disc.

The discs shall be -,it least 35mm dia. with reference letters and numerals not less than 4mni and 8nu-n high respectively. .

The discs shall be mounted on the hub of the handwheel or where this is impractical, they shall be attached to the valve stem by means of suitable brass 'S' hooks and/or jack chain through a hole at the top of the disc.

V-A.30-3 Access

All valves, spindles and handwheels shall be positioned to give good access for operational personnel. It shall be possible either to remove and replace or to recondition seats, gates or gland packings which shall be accessible without removal of the valve from the pipework or, in the case of power operated valves, without removal of the actuator from the valve.

Extension spindles shall be supplied wherever necessary to achieve the specified operating requirements.

V-A.30-4 Hand Operation

All handwheels shall be arranged to turn in a clockwise direction to close the valve or penstock, the direction of rotation for opening and closing being indicated on the handwheels.

The handwheels shall be coated with black plastic and incorporate facilities for padlocking in either the open or closed position.

The operating gear of all valves and penstocks shall be such that they can be opened and closed by one man against an unbalanced head 1 5% in excess of the maximum specified service value and any gearing shall be such as to permit manual operation in a reasonable time and not exceed a required rim pull of 200kg.

Power operated valves shall include equipment for manual operation by means of a handwheel or other suitable device which shall be interlocked with, and fixed to, the power unit.

Headstocks and valves of 50mm nominal bore and above shall be fitted with mechanical position indicators to show the amount which the valve is open or closed in relation to its full travel, i.e. 0.25, 0.50, 0.75, 1 etc.

V-A.30-5 Valve Materials

Valve bodies and other components shall be of corrosion resistant materials, compatible with the medium and of robust industrial design.

For water applications and where specified, valve bodies, discs and wedges shall be of cast iron, with facing rings, seating rings, wedge nut and other trim of corrosion resistant bronze or gun metal.

The valve stem, thrust washers, screws, nuts and other components exposed to the water shall be of a corrosion resistant grade of bronze or stainless steel.

For water works applications, wedge gate, metal seated valve materials shall be in accordance with BS 5163 Table 6A, fitted with a stuffing box and gland seal on the stem. 0il or grease shall not be used on any bearing or seal that may be in contact with the water being controlled.

V-A.30-6 Sluice Valves

All sluice valves, unless otherwise specified shall be of the rising spindle type, have wedge gates and be flanged to NP16 and be in accordance with the relevant clauses of BS 5150.

Valves up to and including DN300 shall be of the resilient seal or metal seal type. Valves larger than DN300 shall have metal seals.

The valves shall be suitable for unbalanced head. A by-pass with gate valve forming an integral part of the valve shall be provided where recommended by the manufacturer for the pressures specified.

Where specified, sluice valves shall be fitted with easing screws and a clean-out

box in the base.

V-A.30-7 Telescopic Valves

All bellmouth telescopic valves shall have cast iron outer sleeves and bellmouths. The outer sleeves shall have machined labyrinth seals and the sliding tubes shall be manufactured from zinc free bronze.

A cast iron stirrup shall be affixed over the top of each bellmouth and these shall be connected to the rising screw thread by means of a stainless steel 'Rose' type coupling. To minimize fouling by rags etc. the valves shall not be fitted with outer guide rods.

V-A.30-8 Non-Return Valves

All non-return valves shall be of a type that will operate without shock.

Valve bodies shall be of cast iron and shall be fitted with renewable type seatings.

In the case of swing gate type valves the hinge pin shall be of stainless steel, mounted in zinc free bronze bushes and extended and fitted with external levers and counter balance weights, all protected by a screen guard.

Other types of valves will be considered. In every case the non return valve shall be selected with full consideration of the system characteristics, and shall avoid valve slam, and have low maintenance requirements.

Where specified, limit switches shall be provided to operate from the external lever. The screen guard being slotted to allow the guard to be removed without disturbing the switch cabling.

V-A.30-9 Butterfly Valves

Butterfly valves shall have a resilient disc seating and be designed for a positive leak-proof shut off at a minimum pressure of 16 bar. Non-wafer types are preferred are preferred.

Butterfly valves shall conform to BS 5 155

Valves for flow regulation shall be of all metal construction.

V-A.30-10 Plug Valves

Plug Halves shall be of the wedge gate type, with cast bodies. The plug surface shall be coated or lubricated to ensure low torque operation with bubble tight shut-off and "non-sticking" materials.

V-A.30-11 Isolating Cocks

For isolation of small bore pipework tappings for instrumentation equipment etc, and for individual component isolation, the cocks shall be stainless steel, quarterturn, ball or plug valves with the operating handle arranged to indicate the open and closed positions. Where specified, means shall be provided for securing the valve body to a front panel or rear surface.

Where corporation cocks are specified, these shall be similar to the above isolating cocks but shall have a detachable key handle for fitting onto a squared operating shaft, the shaft end being marked to indicate the open and closed valve positions.

V-A.30-12 Extension Spindles

Extension spindles shall be adequately sized to prevent buckling and shall be attached to the valve/penstock stem by a suitable adaptor incorporating two muff couplings, scarf lap jointed and pinned with at least two coupling joints included. Universal joints and waterproof sleeves shall be provided where specified. Extension spindles shall be manufactured from 080M40 (EN 8) steel.

Intermediate bearing support or guide brackets of cast iron, with slotted holes for site adjustment, shall be fitted to long shafts where necessary. Bearings shall be of PTFE or similar approved type.

V-A.30-13 Pedestals and Spindle Covers

Penstock and valve pedestals shall be of cast iron or heavy duty, welded, mild steel construction with a substantial base and fixing provision. The base and top of the pedestals shall be machined normal to the axis of the drive shaft.

Where necessary, support guide bushes shall be fitted as the base of the pedestal.

The pedestal height shall be such that the handwheel is approximately 1 meter above the operator's floor level.

Covers of an approved type shall be provided for all rising spindles to totally enclose them when in the fully raised position.

V-A.30-14 Penstocks

All penstocks shall be designed and installed so that the maximum working pressure acts in a seating direction on the gate.

Both gate and frames shall be sufficiently rigid to withstand twice the maximum working pressure and any eccentric pressures created by the tightening of the anchor bolts during installation. All penstock frames shall have a spigot back.

The frame shall be designed to ensure that the gate is supported over not less than two thirds of its depth when the gate is fully raised.

Penstocks shall be of the rising spindle type unless otherwise specified, and the spindles shall be of adequate size to avoid buckling under load.

All spindle nuts shall be self aligning and their length shall be riot less than twice the spindle diameter.

The top part of the penstock frames shall be sufficiently robust and substantial to prevent the frames bowing and if necessary, additional holding down bolts shall be fitted. The penstocks shall be fitted with matching wedges on doors and guides, the wedges shall be fitted with renewable seatings of zinc free bronze. Under no circumstances shall wedges be fitted to the bottom or lower sections of the penstock doors. The wedges shall be adjustable with stainless steel adjusting screws and shall be readily removable.

On rectangular penstocks the inverts shall be flush with renewable synthetic rubber seals on the bottom of the doors. The rubber shall be suitable for the application and of an approved type.

The doors shall have lifting eyes cast in, or eye bolts of sufficient size to permit the lifting of the door against seating pressure.

V-A.30-15 Penstock Materials

Penstock doors, wedge support beams, frames, guides, frame extensions, headstocks and bridge pieces shall be cast iron, of minimum grade 220 to BS 1452. Doors and frames shall be fitted with renewable seatings of zinc free bronze.

Spindles shall be manufactured from stainless steel 431S29 (EN 57) or similar approved material.

V-A.30-16 Templates

Simple templates shall be supplied as soon as possible after approval of drawings to enable the Civil contractor to position the holes for holding down bolts for all penstocks over 1.0m square.

V-A.30-17 Air Valves

Air valves shall be of two types:

1. Single (small) orifice valves (SAV), for the discharge of air during the normal operation of the pipeline.
2. Double office valves (DAV), consisting of a large orifice and a small orifice, These shall permit the bulk discharge of air from the main during filling and air inflow when emptying in addition to the discharge of small quantities of air during normal operating conditions.

Air valves shall be supplied with an independent isolating butterfly valve (DAV) or cock (SAV) which permits the complete removal of the air valve from the main, without affecting the flow of water in the main.

The sizing of the air valve and isolating assembly shall be such that the pressure drop at design flow capacity does not exceed 0,5 bar.

Each air valve assembly shall be suitable for connection to a flange on the pipeline.

At the connection between the air valve and its isolating valve a BSP tapping shall

be made suitable for fitting of a pressure gauge. All tappings shall be scaled by a brass plug and copper compression ring gasket.

Air valves shall operate automatically and be constructed so that the operating mechanism will not jam in either the open or closed positions,

V-A.30-18 Testing

All valves shall be tested in accordance with BS 5155 and pressure and material test certificates shall be submitted to the Engineer for approval.

PART VI - Geotechnical Investigations

PART VI – GEOTECHNICAL INVESTIGATIONS

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VI-A SCOPE

The purpose of the work specified herein is to determine/confirm the type, nature and hydro-geological characteristics of subsurface materials and the extent and conditions of the various materials (including cavities and/or sinkhole-developments) as they exist to the depths in the reservoir area. This is to be accomplished by means of test pits and excavations, core drilling, field testing sampling and analysis, laboratory testing, geological and hydro-geological investigation, field permeability testing and artesian pressure measurements. The Contractor will provide access roads and work-platforms as he deems necessary for the execution of work. The Contractor will also provide a report summarizing and interpreting field and laboratory results.

VI-B QUANTITIES AND LOCATIONS OF HOLES

The limits of work, approximate number and location of drill holes and test pits shall be proposed by the Contractor according to Tender Drawings (but not limited to) and approved by the Engineer.

VI-C MOBILISATION AND DEMOBILISATION

a. Mobilization: mobilization shall consist of the delivery to the site of all plant, equipment, materials, and supplies to be furnished by the Contractor; the complete assembly in satisfactory working order of all such plant and equipment on the job; the movement of rigs and other necessary equipment between the various boring and test pit locations; the setting up of each rig at various boring or test pit locations manned and ready for commencing and continuing the work; and the satisfactory storage at the site of all such materials and supplies.

b. Demobilization: demobilization shall consist of the removal from the site of all plant and equipment after completion of the work and shall include restoration of the area as requested and approved by the Engineer.

VI-D INSPECTION

No work shall be performed in the absence of the Engineer unless authorized by him. The Contractor shall not remove casing or equipment from any completed boring or test pit except with the express permission of the Engineer and not until the Engineer has had the opportunity to obtain all relevant data prior to removal.

VI-E RECORDS

The Contractor shall keep accurate driller's logs and records of all work accomplished under this Contract and shall deliver complete, legible copies of these logs and records to the Engineer on completion of the work in each hole or pit, or at other times as he may be directed. All such records shall be preserved in good condition and order by the Contractor until they are delivered and accepted. The Engineer shall have the right to examine such records at any time prior to their delivery to him. Separate logs shall be made for each hole and test pit. The following information shall be included on the logs or in the records for each hole:

1. Full information on the location, type of boring, diameter, ground elevation, inclination.
2. Location, elevation, depth, type, and number of each sample taken.
3. Driving energy and blow count data for each 15 centimeter penetration of drive sampler and 30 centimeter penetration of casing where the casing is driven.
4. Average rpm and hydraulic advance pressure of drill rig on undisturbed samples, cores, and casing, where the casing is advanced by drilling.

5. Length in centimeters of sampling or coring drive or run.
6. Length and percent of recovery for all samples and cores.
7. Driller's classification or description by depths of the materials sampled, cored, or penetrated, including a description of thickness of zones, moisture conditions, and of conditions of compactness or stiffness of soils materials encountered. This classification or description shall be made immediately following the taking of the samples or cores.

   TCR, Solid Core Recovery (SCR), Rock Quality Designation (RQD), Fracture Frequency, cavity/sinkhole-development detection, degree of karstification and detailed Logging (including weathering, color/percentage and loss of circulation water) shall be carried out by an engineering geologist and indicated on logs of borings. All soil and rock descriptions shall be in accordance with BS 5930 – Section 8.

   % TCR (TOTAL CORE RECOVERY) is the % ratio of the total length of core recovered (rock and soil) to the length of drilling interval.

   % SCR (SOLID CORE RECOVERY) is the % ratio of the solid full diameter rock-core pieces to the length of drilling interval. %SCR isn't calculated for highly to completely and completely weathered soil-like rockmass recoveries.

   % RQD (ROCK QUALITY DESIGNATIONS) is the % ratio of the sum of the lengths of rock-core pieces 10cm or longer to the length of drilling interval. %RQD isn't calculated for highly to completely and completely weathered soil-like rockmass recoveries.
8. Size and lengths of casing used in each bore hole and where added.
9. Elevation of rock if encountered.
10. Elevation of depth of water in holes, daily, at the start of work and after completion of the bore hole until true water table conditions have been established as approved by the Engineer.
11. Elevations and depths of seepage tests and artesian measurements.
12. Elevations and depths at which drill water is lost and regained, and amounts and color of return water.
13. Elevation and depth of bottom of hole.
14. Dates and time by depths when test-pitting, drilling, sampling, seepage testing, and artesian measuring operations were performed.
15. Time required for drilling each run.
16. Time required for seepage tests and artesian measurements.
17. Pressure employed in seepage tests and artesian measurements.
18. Any changes in the drilling action which would be supplemental information to the sampling or coring.
19. Any information or data that the driller may deem pertinent or that may be requested by the Engineer.

The presence of the Engineer or the keeping of separate drilling records by the Engineer shall not relieve the Contractor of the responsibility for the work specified in this paragraph.

VI-F CONTAINERS

a. General The Contractor shall furnish litter size wide mouth jars, 10kg capacity moisture proof bags, undisturbed sample and core boxes, and accessories meeting the specified requirements, or approved as equal by the Engineer. The Contractor shall furnish as many containers as may be required. All such containers will become the property of the Engineer and the cost thereof shall be included in the Contract price for the applicable item for which payment is provided.

b. Core Boxes. Longitudinally partitioned core boxes constructed of lumber or other approved materials, shall be used for all rock cores, selected cores of soil, and selected cores of weathered zones taken from within the rock. Where the Contractor elects to advance a hole by coring in overburden, such core as may be designated by the Engineer shall also be placed in core boxes. The soil and weathered zones shall be preserved in undisturbed boxes or core boxes as directed by the Engineer. As many core boxes as may be required shall be used in submitting each core or group of cores. Core boxes shall be completely equipped with all necessary partitions, covers, hinges, screws for holding down the cover, identification plates, tags and other accessories.

VI-G LABELS

Each bag and core box shall have printed or typewritten labels, shall be identified with water-proof and wear-proof labels or markings indicating the following:

Project

Hole No._____ Location _____

Hole No._____ of _____Jars

Jar No._____ of _____Bags

Top Elev. of Hole _____

Depth of Sample _____ to _____

Description of Material_____

VI-H BORINGS

a. General. The Contractor shall make vertical borings of minimum 101 mm in bedrock and 200 mm in overburden. Coring will be continuous from the top of rock to the bottom of hole.

b. Equipment and Supplies. The Contractor shall furnish and use sufficient numbers of drill rigs and associated equipment to successfully complete the project within the designated time scheduler. The drill rigs shall be capable of drilling vertical holes to a depth of 50 meters. Some rigs shall be provided with whirling capability but all rigs shall be provided with hydraulic feed mechanic lams and catheads, and capable of taking drive samples and double tube core barrel rock cores to the depths required. The Contractor shall supply such equipment or accessories necessary for proper positioning of vertical borings.

All borings may be drilled with minimum 101 mm. Drilling mud will not be allowed because of permeability testing requirements.

The Contractor shall provide sufficient heavy-duty casing of such a type to be driven or drilled through the overburden to sound rock. The Contractor shall furnish drill rods, piping, pumps, water, tools, power and all other supplies required to execute the borings to the required depths by the procedure described. Prior to mobilization, the Contractor shall submit to the Engineer for approval a list of equipment he will use.

c. Additional Equipment. If it appears during the course of the work that the Contractor will not complete the contract work within the specified contract period, he shall be required to obtain additional equipment, as deemed adequate by the Engineer, to insure completion of the work as specified. When the Contractor is ordered by the Engineer to use additional equipment or rigs to complete the work on schedule, he shall employ the most expeditious measures and act with the utmost promptness to comply with the Engineer's instructions.

d. Advancing and/or Cleaning the Drill Hole. Samples taken above the water table shall be taken from a dry hole. Advancing and/or cleaning the dry hole to the sampling depth shall be accomplished using a clean out auger or approved equivalent so as to keep the hole dry and not disturb the virgin material at the depth to be sampled. Below the water table any method of cleaning the hole to the sampling depth that does not disturb the virgin material shall be used. If jetting is used, upward or baffled jets shall be required. Below the water table, a head of water greater or equal to the water table, shall be kept in the boring at all times, including the duration of the withdrawal of tools. Where seepage tests or double tube core barrel has introduced water into the hole above the water table, methods other than those required in a dry hole may be used at the convenience of the Contractor where approved by the Engineer. When core drilling through a boulder or ledge rock has been accomplished the cored portion of the hole shall be reamed out as required to advance the casing. If blasting is done, the Contractor shall obtain all necessary permits and shall comply with all laws, rules, regulations and ordinances governing blasting operations. Recirculated or clean water shall be used in overburden below the water table, in holes where seepage tests are designated or requested, and in rock coring. The holes shall be flushed out with clean water prior to testing in accordance with the appropriate Technical provision.

The Contractor shall be responsible for keeping the hole open at all times during the drilling and until all tests or other work in connection with the hole has been completed and the Contractor has been authorized by the Engineer to backfill the hole. In the event of collapse of the hole prior to receipt of authorization to backfill, the hole shall be reopened, in a manner specified by the Engineer, at the Contractor's expense.

e. Artesian Flow. Artesian flow may be encountered when drilling. Each time such flow is encountered, the advancement of the bore hole shall be immediately interrupted and the artesian rise in water or pressure in the casing measured in accordance with Paragraph ART-17&18.

f. Advancing the Casing. The casing shall be advanced by hammer, rotary drill, or any method approved by the Engineer, in such a manner to keep the hole open, and insure a tight seal in sound rock. The casing shall be advanced at a sufficient distance behind the sampling operation so as not to disturb the material to be sampled.

VI-I SAMPLING AND CORING IN BORINGS

a. General. Samples and cores shall be taken at designated elevations, with the designated sampler or core barrel as directed by the Engineer. The hole shall be properly advanced and cleaned in accordance with Subparagraph ART-09 d, Advancing and/or Cleaning Drill Hole, prior to sampling. Sampling shall be done by such means as to prevent the inclusion of wash in the sampler. The depths of starting and stopping drives or runs shall be accurately established to the nearest 10 cm.

b. Coring in Overburden. Where specifically requested by the Engineer, double tube core barrels with or without liners will be used to core overburden, generally in dense materials, boulders, and highly weathered rock. The speed of rotation, rate of hydraulic advance, and length of run shall be adjusted so as to provide minimum soil disturbance and maximum recovery. The speed of rotation shall not exceed 200 RPM unless otherwise approved by the Engineer and the maximum length of run shall be such as to provide a 150 cm long sample within the liner, when approved by the Engineer.

c. Rock Core Drilling. The casing through overburden or weathered rock shall be sealed tightly in sound rock prior to commencement of rock coring. The coring of rock with double tube core barrels 101 mm shall be in accordance with Subparagraph b, except that the maximum length of run may be increased to 3 meters when approved by the Engineer. The Contractor shall exercise particular care in recording water losses, rod jerks, and other unusual coring experiences that, supplementing the core record, will indicate the nature and the extent of any fracturing.

VI-J CASING

a. General. The advancing of casing shall be in accordance with Subparagraph ART-09 f, Advancing the Casing.

b. Removal of Casing. Except as otherwise authorized by the Engineer, all casing shall be removed on completion of the work, and it shall remain the property of the Contractor. Casing shall not be removed until authorized by the Engineer.

VI-K TEST PITS

a. General. A test pit shall be any excavation in soil, cinders, hardpan, decomposed rock or other unconsolidated or partially consolidated overburden which has an open cross-sectional area large enough to permit safe, efficient engineering inspection in situ density testing and disturbed bag sampling (or undisturbed Shelby sampling). Bag samples totaling 450 kg or more may be required. The Contractor shall comply with all safety regulations governing this work.

b. Equipment and Supplies. The Contractor shall furnish all equipment and supplies necessary to perform the work.

c. Excavation. The test pits shall be excavated to the required depths.

d. Sampling. All sampling shall be performed by the Contractor as requested by the Engineer and labeled and preserved as specified in ART-08 and ART-14, respectively.

e. Barricades. Immediately upon completion of excavation operations for each pit the Contractor shall construct an enclosure guard around each pit, set back about 1 meter from the edge of the pit. The enclosure shall be constructed of materials selected by the Contractor. The enclosure shall be constructed in such a manner that no person or animal can fall into the test pit. In addition, it is the Contractor's responsibility to ensure that the barricades are placed; the liability associated with the failure to do so shall lie with the Contractor.

f. Refilling of Test Pits and Test Trenches. The test pits shall be refilled when directed by the Engineer/as directed by the Engineer. The refilling of test pits will not be measured for payment and all costs in connection therewith shall be considered a subsidiary obligation of the Contractor.

g. Logging. The test pits (TPs) shall be logged (classification by depths of the materials excavated, including their moisture and stiffness / consistency) by an engineering geologist, the log and scaled-photo of TPs shall be presented in geotechnical investigation report. All soil and soil-like rockmass descriptions shall be in accordance with BS 5930 – Section 8.

VI-L ABANDONED BORINGS AND FALSE STARTS

No measurement or payment will be made for borings/TPs abandoned or lost before reaching the required depths. Except with the specific permission of the Engineer, the Contractor shall not abandon or complete any boring/TP, or remove any casing or drilling equipment, without first affording the Engineer the opportunity of obtaining the position and depth of the boring/TP prior to abandonment or completion, and any other information which the Engineer may require. The Contractor shall furnish the Engineer with complete records and samples for the depth penetrated in the manner hereinafter prescribed for completed borings/TPs.

VI-M PRESERVING SAMPLES AND CORES

a. General. The Contractor shall provide all material, equipment and labor necessary for preserving soil samples and rock cores. Wax for sealing sample containers shall be Socony Vacuum Oil Company Product 2300, or approved equal. The preserving and storage of samples and cores shall be a subsidiary obligation of the Contractor in connection with obtaining the samples or cores and no extra payment shall be made for preservation or storage of samples and cores.

b. Test pit Samples. Bulk samples selected by the Engineer from test pits shall be preserved in waterproof bags and shall be clearly marked with two (2) waterproof labels, one wired to the bag and one placed inside the bag. Jar samples taken as directed by the Engineer shall be scaled by double dipping the cap and threads into wax immediately after capping. Undisturbed samples requested by the Engineer shall be moisture proofed and handled accordingly and as requested by the Engineer.

c. Undisturbed Samples in Liners. After inspection by the Engineer, the ends of the sample tubes shall be cleaned out to a depth of 2 inches and a seal provided of micro crystalline wax, such as Socony Product 2300 or equal. A metal disc, having a diameter slightly less than the inner diameter of the tube shall be inserted into the wax at a distance of 2.5 cm from the end of the soil sample. The wax plug shall be flush with the ends of the tube and a metal cap shall be placed over the ends, taped and sealed with two coats of wax. Liners which are only partially full should be filled with wax before capping. Special care shall be made to mark the top and bottom of liner. Material taken from the shoe and the top shall be placed in separate litter jars and marked accordingly and sealed in accordance with the requirements of Subparagraph b.

   The wood Spacers / blocks together with labels shall be used to indicate areas in which samples are / will be transported to lab for testing.

d. Undisturbed Double Tube Core Samples Without Liners. After inspection by the Engineer, the undisturbed core sample shall be wrapped in polyethylene, coated with wax twice, and wrapped in cardboard, or other stiff material approved by the Engineer. Special care should be taken not to break or disturb the sample during the handling.

   The wood Spacers / blocks together with labels shall be used to indicate areas in which samples are / will be transported to lab for testing.

e. Soil and Rock Cores. All rock cores and all soil cores such as undisturbed samples shall be arranged neatly in the partitioned boxes constructed and marked in the same sequence in which they occurred before removal from the hole. Facing the open box with the hinged cover above the open box below, cores shall be arranged neatly in descending sequence beginning at the left end of the partition nearest the hinges and continuing in the other partitions from left to right. The highest core shall be placed in box 1 and the lowest portions of the core shall be placed in the other boxes in consecutive order. The runs shall be sectionalized by wood Spacers showing depth, length of run, fractures and their estimated width, and recovery. Core loss blocks shall be used to indicate areas in which no core is recovered. Core sections as designated by the Engineer, shall be wrapped in polyethylene sheets, coated with wax twice, and wrapped in cardboard or other stiff material approved by the Engineer.

   The wood Spacers / blocks together with labels shall be used to indicate areas in which samples are / will be transported to lab for testing.

VI-N STORAGE AND DELIVERY OF SAMPLES AND ROCK CORES

a. General. The Contractor shall be solely responsible for preserving all samples in good condition. He shall keep samples from undue exposure to the weather. The Contractor shall keep all descriptive labels and designations on sample jars and boxes clean and legible until final acceptance by the Engineer. The Contractor shall comply with all requests of the Engineer concerning the care and protection of samples.

b. Storage. Upon completion of drilling and sampling operations in each hole, or as necessary to protect samples, all boxes containing samples and cores shall be delivered to a structure provided by the Contractor near the work site. Undisturbed samples shall be transported with the tubes in a vertical position, top down, to prevent consolidation and segregation of pore water. Boxes containing disturbed samples and core boxes shall be so arranged in the storage area that the samples and cores can be conveniently and readily examined by the Engineer. Undisturbed samples shall also be stored in an orderly method. Upon request of the Engineer, the Contractor shall furnish a laborer to assist the Engineer in inspecting the samples and cores. The Contractor shall provide all transportation and labor required for storage of the samples and cores at the desired location.

c. Shipment of Selected Samples. Upon request by the Engineer, soil samples and cores shall be boxed by the Contractor as described below and shipped to the Laboratory approved by the Engineer. Samples not directed to be shipped to the above address shall remain at the core storage area at the site. Every precaution shall be taken to avoid damage to samples and cores, especially to undisturbed samples, as a result of careless handling and undue delay in shipping. Undisturbed samples shall be shipped in partitioned wooden boxes made from lumber 6cm, or heavier lumber. The sample tube shall be placed vertically top down, in the box and well-packed in excelsior or other equal material to protect the sample against vibration. The undisturbed sample and core boxes shall be marked "Do Not Jar or Vibrate" and "Handle, Haul and Ship in a Vertical Position". Containers containing glass jars shall be marked as such.

VI-O SEEPAGE TESTS

a. General. Seepage tests shall be performed in bore holes and at depths designated by the Engineer. Prior to performing the seepage tests, the bore hole shall be cleaned out and flushed with clean water to the bottom of the hole by means of a shielded jet or deflected jet as approved by the Engineer, so that all material is removed from inside the bore hole and a clean surface of undisturbed material exists at the bottom of the hole. The rate of seepage shall be determined by one of two methods described below. After performing the above tests the bore hole may be advanced without advancing casing, cleaned as described above and the rate of seepage again determined. Ground water table shall be determined for each seepage test. The data to be recorded for each test which are common to each of the two test methods are as follows:

- Inside diameter of casing.
- Height of top of casing above ground surface.
- Length of casing during test.
- Diameter of bore hole below casing.
- Depth to bottom of boring from top of casing.
- Depth to standing water level from top of casing.
- Description of exposed material tested.

b. Falling Water Level Method. The casing shall be filled with water and the rate of drop in the water level in the casing determined by observing the depth of the water surface below the top of

the casing at 1, 2 and 5 minutes after the start of the test, and at 5 minute intervals thereafter. The record of measurements shall include the depth of the water surface below the top of casing before and after filling of the casing, the time, and tile amount of the drop measured from the start of testing for each observation. Observations shall be continued until the rate of drop in water level becomes negligible or until stopped by the Engineer. If the drop in water level, as described above, is too rapid to permit accurate observations to be made, then the method described below shall be used.

c. Constant Water Level. Water shall be added in accurately measured quantities by pouring from calibrated containers or by pumping through a water meter at a rate of flow sufficient to maintain a constant water level at or near the top of the casing for a period of not less than 20 minutes, until stopped by the Engineer. The record of measurements shall include the depth of the water surface below the top of casing before filling and during the test period, the length of time during which the water in the casing was maintained at constant level, and the amount of water necessary to be added to maintain the constant water level in the casing at 1, 2, and 5 minutes, and at 5 minute intervals thereafter, as directed by the Engineer.

Note: The water infiltration test may be performed in TPs as directed by the Engineer.

VI-P PRESSURE TESTING IN ROCK

a. General. Pressure testing of weathered and sound rock shall be performed as directed. The apparatus used shall consist of a single pneumatic or mechanical expanding packer to seal off a section of the bore hole for testing. The packer and drill rods shall be calibrated to determine friction losses in the system. The length of the packer when expanded shall be about five (5) times the diameter of the hole. It is the Contractor's responsibility that the packers used are compatible with the size casing used in each borehole. Water lines shall be arranged so that water may be pumped below the packer. The system shall include a pressure gage, water meter, a manually adjusted automatic pressure relief valve, and a pressure pump. After each three (3) meter depth of hole is drilled, the packer shall be seated so that the entire three (3) meter length of hole can be pressure tested. Water under pressure shall be pumped into the test section and the readings recorded. Upon completion of the test, the packer shall be removed, the hole drilled deeper, and the packer reinserted after an additional three (3) meters of hole have been drilled. The packer shall be seated each time at an elevation that will allow the full three (3) meter length of newly drilled hole to be tested.

b. Water Pressures, Duration of Tests, Data to be Recorded The pressure testing shall be performed in five (5) steps for each complete pressure test with the maximum pressure (P_3) based upon the vertical depth to the mid-point of the test section. The value of P_3 will be determined by the Engineer but will be in the range of 0.35 to 10 Kg/cm². In no case will the pressure at the test section exceed 0.23 Kg/cm^2 per meter of depth. The following table shows "specified ratios" of pressure and times specified for each step of pressure test.

Step No.	Pressure (P)	Time(minutes)
1	$P_1 = 1/3\ P_3$	5
2	$P_2 = 2/3\ P_3$	5
3	P_3 (determined by test depth)	10
4	P4 = 2/3 P3	5
5	P5 = 1/3 P3	5

Additional data to be recorded in each test are as follows:

- Elevation of bottom of hole at time of each test.
- Elevation of packer.
- Elevation of ground water table at the time of the test.

- Elevation of piezometric level in artesian strata.
- Length of test section.
- Radius of hole.
- Length of packer.
- Height of pressure gauge above ground surface.

VI-Q ARTESIAN MEASUREMENTS

a. General. Where artesian flow is encountered the Contractor shall measure its pressure as directed by the Engineer.

b. Equipment. The Contractor shall supply all necessary equipment for performing these measurements, including two Bourbon Gages, a watertight casing cap with "Y" connection and bleeder valve, and expansion plugs to seal off a portion of the hole for testing. The expansion plugs shall be expandable rubber packer having a length about 5 times the diameter of the hole. The Bourbon Gages shall be calibrated in meters of water relative to atmospheric pressure. One gage shall have a range of 0 to 6 meters and the other a range of 0 to 30 meters.

c. Procedure. Where the artesian pressure is of such magnitude that the water in the borehole does not rise above the top of the casing, the pressure shall be measured and recorded as the number of meters and tenths of a meter between the natural ground water level and the level of the water in the casing. Where the artesian pressure is of such a magnitude that the water rises above the highest elevation to which the casing can be practicably extended, the pressure shall be measured by means of a Bourbon Gage fitted to a watertight casing cap by means of a "Y" connection equipped with a bleeder valve.

After each measurement of artesian pressure, the bottom of the borehole shall be advanced at least 0.3 meters but not more than 1.5 meters below the elevation at which the artesian pressure is encountered. If the artisan condition persists after advancing and cleaning out the borehole, additional measurements shall be made.

Records shall be kept of the gage readings and the vertical distances in meters and tenths of meters between the center of the gage, the natural ground surface and the natural ground water level.

VI-R SURVEYING AND HOLE MARKERS

Upon completion, each test boring, test pit, and trench shall be surveyed to determine its exact location and elevation. A piece of plastic pipe filled with neat cement shall be installed by the Contractor to mark the hole. A suitable rust proof metal tag shall be attached to each marker showing the hole-number, depth, and surface elevation. LABORATORY TESTING OF SOIL SAMPLES AND ROCK CORES

a. General. Laboratory testing will be completed on disturbed and undisturbed samples of soil and on lengths of rock core selected by the Engineer and shipped to a laboratory proposed by the Contractor and approved by the Engineer.

b. Testing Laboratory. The laboratory testing shall be performed by an approved laboratory.

c. Type and Approximate Number of Tests. The complete laboratory testing program cannot be determined until the field exploration has been completed and the number and condition of all the samples known.

d. Submittal of a final report. A written detailed report containing the results of the laboratory testing program shall be submitted following the completion of the work in 5 copies to the Engineer for review , then the Contractor will issue the finalized report (5 copies also). The report should identify also the soil strata (including bearing capacity and settlement for each and

every type of project specific structure) and any potential geotechnical problem (such as sliding, instability and etc.) and set out the hydro-geological status of the site. The report shall contain the summary of the results and the procedures used. The report shall contain the results of the field testing (water Pressure tests in rock, seepage tests,…) and the summary of the results as well as the results of the geological surveys and conclusions. Appendices shall contain descriptions of analytical procedures and all pertinent assumptions and calculations used in the interpretations, including anchor trenches for lining complex.

PART VII - Particular Specifications for the Full Lining System for Dam and Reservoir

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VII-A PARTICULAR TECHNICAL SPECIFICATIONS FOR LINING SYSTEM

Note: In the event of any contradiction, conflict or inconsistency between this Particular Specifications and the other parts of the Technical Specifications, the provisions and terms of this Particular Specifications shall prevail.

VII-A-1 Description of the work

This work shall consist of designing, furnishing and placing a membrane complex on prepared surfaces in accordance with the Specifications, and in conformity with the lines, grades, thicknesses and typical cross sections shown on the plans or established by the Contractor and approved by the Engineer.

The Contractor shall provide all adhesives, tapes and welding material recommended by waterproofing sheets manufacturer for bonding to substrate (if required), and for waterproof sealing of joints between membrane and flashing, adjoining surfaces and projections through membrane. The Contractor shall also provide all types of material and accessories for flashing and welding as recommended by the manufacturer.

VII-A-2 Construction Requirement

At least thirty (30) days prior to the date he intends to order the membrane complex materials the Contractor shall make written request for approval of: the brand of materials and method of installation he intends to apply, from the Engineer.

The written request shall include all necessary manufacturer's instructions and recommendations relevant to the physical properties of the proposed sheets, the methods of storage, handling, laying, jointing, attachment, and protection. No ordering of material shall be effected before obtaining the written approval of the Engineer on the above.

Unless other subgrade preparation is called for on the plans or appears as a pay item in the Bill of Quantities, the Contractor shall, as a part of the work and prior to the delivery of the material for the membrane complex, prepare the bed surface by sprinkling, blading, rolling, and lightly scarifying where necessary, until the proper slope is obtained. However, in the process of shaping the bed, the originally compacted crust or top portion of the bed shall be disturbed as little as possible. When completed and ready for the membrane construction, the bed shall be well compacted, smooth, hard and uniform, all irregularities having been bladed out and rolled down.

The membrane complex shall be unrolled directly on the surface. Membranes shall be overlapped to a minimum of twenty centimeters, and shall be welded on site to seal the membranes and ensure water tightness to these joints, all in accordance with Manufacturer's instructions and recommendations. The strength of the welding shall be at least equal to that of the membranes.

Installation shall be scheduled to minimize period of exposure of membrane complex materials.

Equipment and vehicles shall not be operated on the fabric. Damaged fabric shall be repaired, at the Contractor's expense, by placing new fabric over the damaged area in a manner that meets the overlap requirements for horizontal placement. Vertically placed fabric shall be replaced in its entirety.

VII-A-3 Investigation

Based on the previous geotechnical investigation and the tender documents, the Contractor shall submit a program of the additional geotechnical and geophysical investigation, he judged necessary to complete the previous investigation and necessary for the preparation of the construction detailed design of the full lining of the dam and reservoir, in addition to the foundation treatment.

The main purpose of the geophysical investigation is to detect cavities and voids in the foundation soil, since these voids can jeopardize the stability and may cause damages to the membrane to be

installed and may form a source of incoming underground water. The voids and cracks to be detected are the ones having width that can harm the membrane in case of washing of the material filling the crack and the voids (width is related to the type of membrane), and any geological anomalies that may be the source of any future malfunction of the membrane.

The main aim of the geotechnical investigation is to complete the data extracted from the geophysical investigation and to reveal the characteristics of the foundation. The geotechnical investigation shall include the drilling of boreholes, installation of piezometers, insitu testing and laboratory testing in addition to exploratory trenches (if needed and/or requested by the Engineer).

The investigation shall also cover the areas where previous slope sliding occurred and the areas susceptible to slide and any area judged to be necessary to conclude the mechanical and physical properties of the foundation. These data will be necessary for stability checking and treatment design of foundation and of the membrane complex.

The piezometers installed in some (or all, as directed by the Engineer) boreholes will serve to monitor the underground water levels (after air-lifting) during different seasons, during the execution phase. Information needed for the design of the drainage system to be performed (and/or confirmed) by the Contractor.

The boreholes situated under the lining system, shall be closed (grouted as directed by the Engineer) on all their depths by using cement grout to prevent the underground water intrusion (infiltration and/or exfiltration) through it.

The Contractor is required at the start of the execution works to submit a detailed investigation program together with a detailed method statement and a program of execution of these investigations in concordance with the general project program of work.

VII-A-3-1 Geophysical Investigation

The specifications given below for geophysical investigation can be modified, if found necessary by the contractor, and his method statement should show the advantages of any modification.

VII-A-3-2 General Conditions

The proposed geophysical investigation shall be done using the “Ground Penetration radar-GPR” technique. However, the Contractor can propose other similar (or more accurate) techniques for geophysical investigation.

It aims to reveal the probable locations of cracks, voids, cavities and irregularities in the substratum of the reservoir bottom and slopes, prior to their treatment. This survey should respect, at least, the following conditions:

1- Works shall be done on dry soil

2- Topographic survey shall precede the geophysical survey

3- Geophysical survey lines shall constitute a grid made of profiles spaced by 1.5m in both directions.

4- Discovered anomalies shall be marked on ground by a topographic surveyor for future inspection by excavation.

5- Substratum to be investigated, shall be leveled by spreading fine or granular backfill to eliminate irregularities, in order to enhance the survey quality

VII-A-3-3 Equipment and Principles - GPR

GPR is an electromagnetic geophysical method that detects interfaces between subsurface materials with differing dielectric constants. The GPR system consists of an antenna, which houses the transmitter and receiver and a profiling recorder, which processes the received signal and produces a graphic display of the data.

The transmitter radiates repetitive short-duration electromagnetic waves into the earth from an antenna moving across the ground surface. These radar waves are reflected back to the receiver by interfaces between materials with different dielectric constants. The intensity of the reflected signal is a function of the contrast in the dielectric constant between the materials, the conductivity of the material through which the wave is traveling, and the frequency of the signal.

Subsurface features which commonly cause such reflections are:

1- Natural geology such as changes in sediment composition, bedding and cementation horizons, voids, and water content; or

2- Unnatural changes to the subsurface such as disturbed soils, soil backfill, buried wells, tanks, pipelines, and utilities.

The profiling recorder processes the signal from the receiver and produces a continuous cross-section of the subsurface interface reflections, referred to as reflectors.

GPR data are output from the recorder as strip charts, which present the data as a continuous profile.

A GPR survey is conducted along transects which are measured paths along which the GPR antenna is moved.

Depth of investigation of the GPR signal is highly site-specific and is limited by signal attenuation (absorption) in the subsurface materials.

Signal attenuation is dependent upon the electrical conductivity of the subsurface materials.

Signal attenuation is greatest in materials with relatively high electrical conductivities and lowest in relatively low-conductivity materials.

Depth of investigation is also dependent on the antenna's transmitting frequency. The requested depth of investigation of this project will be defined by the Contractor to satisfy himself and guarantee the installed lining complex based on the geological and geotechnical surveys done previously or to be done during the project execution.

VII-A-3-4 Field Procedures

A GPR trial investigation shall be performed prior to starting the survey. GPR cross sections (transect lines) shall be performed over random areas of the site to calibrate the GPR equipment and characterize overall site conditions.

The GPR survey shall be performed along a series of parallel transect lines distant of 1.5m. Additional lines shall be acquired in the areas of interest.

The cross sections shall be marked by red survey paint marks. The location of the antenna along a section line shall be electronically marked on the GPR data to allow correlation of the data with the actual ground locations.

Anomalies shall also be numbered on the ground with red survey paint marks for a later topographic survey.

VII-A-3-5 Topographic Mapping

This mapping aims to make the topographic map along measurement track which will be used as a standard map in this project, in order to determine the correlation between the object position on the ground and the topographic details of the objects on the surface, vertically or horizontally.

The outputs of the Topographic Mapping are topographic maps and underground cavities details that can be presented on hardcopy as map sheet or digital copy.

VII-A-3-6 Results

The results of the GPR trial investigation shall indicate the maximum effective depth of investigation below land surface based on the wave velocity. The depth of investigation is based upon the two-way travel times of the GPR signal traveling through the subsurface soil.

Potential voids and/or sinkhole-developments located below the maximum effective depth of investigation and which could not have been detected by the GPR investigation, shall be considered as deep enough and harmless to the membrane performance.

Nevertheless, the solid confirmation of a void or cavity should be made throughout trial pits over the anomalies area.

The geophysical survey and assessment of this site shall be done by a professional and experienced team (for which CVs should be submitted to the Engineer for approval). Furthermore, the Contractor should submit a detailed method statement with all the equipment details, surveys works methodology, program of works and all necessary details, for the approval of the Engineer, prior to start these works.

VII-A-3-7 Geotechnical Investigation

Refer to Part VI- Geotechnical Investigation- of this technical specifications

VII-A-4 Construction design

The construction detailed design should include mainly: the foundation treatment, the drainage system, the membrane complex and the physical protection. The main aspects to be covered in the design are: hydraulic, geotechnical, structural. Mechanical and any other necessary aspect.

The design shall be based on:

- Review of all previous investigations and reports
- Topographic survey of the whole project area
- Full surface geological survey (on new topographic survey basis) to be done by an experienced geologist that his CV is to be submitted for approval, to complete or update the geological surveys, done previously. This task shall also include the definition of the geotechnical and geophysical investigation extension, locations and the tests types and distribution. The geological survey should also define the parts of the slopes where potential sliding may occur based on of the soil and slopes. These areas will be subject to more investigations and analysis.
- Execution of the new geophysical and geotechnical investigation

The main aspects to be covered by the construction design, and not limited to:

- Foundation treatment against cavities and voids
- Slope stability including seismic loads, saturated conditions, waves, rapid drawdown,… and proposal for stabilisation (excavation, flatting,…)

- Drainage system to guarantee the dissipation of the uplift pressure, stop the fine elements migration and to divert the bypassing water into the outlet chamber in the reservoir bottom. The design should include detailed calculation of the expected capacity of the drainage system, the distribution of trenches and dimensions, the thicknesses of the drainage layer, the characteristics of the geotextile sheets,…
- Surface preparation based on the requirements of the membrane complex supplier.
- Design of the geomembrane complex and physical protection, able to:
  - Resist the harsh weather of the area (snow, ice, winds, significant temperature variation in the area, running surface water,…). Contractor to refer to the hydrological report and to weather data of meteorological stations around the project area
  - Bridge of any local or continuous void of less than 50cm span
  - Support a maximum water head (30m)
  - Minimum life duration of 50 years
  - Resistant to UV for at least 50 years
  - Stable against winds (160km/h),
  - Stable against waves (50cm),
  - Stable against rapid drawdown
  - Flexible
  - Resistant to puncture, especially for the dam facing
  - Stable on the slopes of the supports (dam and berms and slopes) and their geotechnical conditions with the possibility of voids formation under the complex in the future, the hydrogeological conditions and the possibility of existence of underground water pressure,…
  - Durable against damage by vegetal roots

The main output of the membrane complex and physical protection design, shall include, but not limited to:

- Slope stability output with the proposed geomembrane complex showing that are stable or propose any measure to stabilise it (including seismic loads and saturated conditions, waves, rapid drawdown
- The selection of the membrane complex components (lower protection, membrane and upper protection): type, materials, characteristics, dimensions, properties,…
- The need or not of the lower protection and upper protection
- The selection of the physical protection components: type, materials, characteristics, dimensions, properties,…
- Conditions of application of the membrane complex
- The details, the types, the spacing and the distribution of the anchors based on the type and characteristics of the membrane, the site conditions and the stability requirements of the complex. Anchors on the peripheries are necessary.

- Detailed mode of transportation, storage and placement, along with the staff to be mobilized and the expected daily production
- Detailed testing to be carried out during placement to ensure a perfect future behavior

In addition to the full lining design, the Contractor will also release detailed drawings for the 2 systems:

- Inflow control system:
  - Important erosions are localized on the extension of the thalwegs dominating the reservoir. There is a main thalweg draining water of Brissa spring into the reservoir and causing deep erosions in the reservoir slopes and important deposits on the reservoir bed. There is another one on the left side of the slopes that also brings important deposit volumes. Also, other less important thalwegs are draining the water into the reservoir causing also, but less, erosions and deposits.
  - The construction design should be based on the tender design which includes the construction of inflow control structures. This design incorporates the training of these water courses by concretes structure with sediment and gravel traps followed by concrete chutes along the slope and ending by stilling basins.
  - The design criteria of these structures shall be based on the output of the hydrological study done previously and the filling curves of the reservoir through years between 2011 and 2023 concerning the expected flows during different months of the reservoir filling and the expected volumes of the solid deposits.
- Diversion system:
  - It becomes clear that incoming water is not sufficient to therefore the reservoir on an average year where the need to bring water from other hydrological basin. An additional diversion system is also needed in order to increase the inflow quantities to the reservoir.
  - The construction design shall include the diversion system as proposed in the tender drawings aiming to divert water from nearby watersheds in order of 1Mm3 yearly. This quantity represents the additional needed volume during the wet season extending over 3 months.

VII-A-5 SURFACE PREPARATION AND DRAINAGE LAYER

The contractor is responsible of the surface preparation as the roughness and the stability of the foundation is essential to the durability of the lining.

Based on the geophysical and geotechnical investigation outputs, the detected voids, cracks and cavities, which can be the source of any kind of risk or damage to the membrane complex, should be treated prior to the surface preparation. Treatment should include mainly the cleaning of these voids and filling with porous concrete or ordinary plain concrete. The method statement of this treatment should be submitted by the Contractor and will be subject to the Engineer approval.

The upstream face of the dam should be stabilized and smoothed with a concrete poured on the rip rap protection layer. This should penetrate the protection by almost 0.80m to block any stones movement, on one hand and on the other, to eliminate any protruding element susceptible to punch or injure the membrane.

On the left side abutment, where the foundation is made of slope wash, a compacted embankment made of a continuous gradation, non-plastic, material watered and compacted in layers of less than 50cm thickness. The Dmax of the material should not exceed 100 mm. Non-compacted material lying in the skin of the embankment should be removed in order to offer a sound foundation to the membrane. The shape of the embankment is provided in the tender drawings.

The walls of the reservoir, should also be smoothed either by removing protruding zones or by concreting or backfilling using non-plastic continuous gradation compacted material. Corresponding Dmax should not exceed 40 to 100mm depending on the thickness of the zone to be backfilled.

The floor of the reservoir needs also to be smoothed mainly by motor grader work after removing all blocs setting on the surface. A systematic vibrating compaction of the surface should be carried out in order to densify the surface and locate any eventual shallow void.

The area which is already covered with the PVC membrane complex (membrane + geotextile) should receive a preparation to be defined by the Contractor in his proposal. It should concern mainly the bubbles' zone and the boundaries.

In case the existing membrane can be kept, it should be dismantled, the foundation should be treated, the drainage system installed and the membrane reinstalled. The connection of the new membrane with the existing one should be detailed by the Contractor, demonstrating a perfect continuity of the watertightness between both membranes

Underneath the membrane complex, a drainage system is required. The main role of the drainage system under the membrane (on reservoir bottom and upstream slopes), is to intercept and convey the bypassing water (responsible of the bubbles) to the dam outlet gallery. Thus, will prevent the uplift on the membrane complex and prevent any potential damage and limit the risks of local collapse. This drainage system will allow also to limit the migration of the fine elements of the foundations soil. Whatever is the selected type of the membrane, it is mandatory to have a drainage system on reservoir bottom and on upstream slopes, which can be, as a minimum:

The drainage system could consist of draining gravel material (trenches and layers), with geotextile or other type of efficient drainage system proposed by the Contractor. The necessary details of the proposed drainage system under the membrane shall be proposed by the Contractor and should be justified technically taking into consideration that any future damage of the membrane caused by underground water falls within the responsibility of the Contractor and will be included in the Defect Insurance of 10 years to be delivered to the Employer at the contract signature.

A detailed method statement of the surface preparation and drainage provisions addressing almost all possible situations should be presented prior to execution.

VII-A-6 MEMBRANE COMPLEX

The membrane is made of a complex made of multiple layers providing the required watertightness and resistance to punching and other weather agents. It should be so strong to provide bridging of any local or continuous void of less than 50 cm span.

The contractor should provide, prior to start the installation of this complex, a method statement demonstrating that the proposed membrane is compatible with the maximum water head and the required durability of a minimum of 50 years. Among the elements to be provided:

1- Detailed description of the proposed membrane and of the lower and upper protections (if they exist)

2- Calculation note justifying its resistance to the present stresses (30m head)

3- Resistant to the harsh weather of the area (snow, ice, winds, significant temperature variation in the area, running surface water,…)

4- The resistance to UV on at least 50 years

5- Stable against winds (160km/h), waves (50cm), rapid drawdown …

6- Stable on the slopes of the supports (dam and berms and slopes) and their geotechnical conditions with the possibility of voids formation under the complex in the future, the hydrogeological conditions and the possibility of existence of underground water pressure,…

7- Durability against damage by vegetal roots

8- The details, the types, the spacing and the distribution of the anchors based on the type and characteristics of the membrane, the site conditions and the stability requirements of the complex. Anchors on the peripheries are necessary.

9- References of satisfactorily operating reservoirs waterproofed with the proposed type of membrane, along with certificates of the owners;

10- Detailed mode of transportation, storage and placement, along with the staff to be mobilized and the expected daily production;

11- Detailed testing carried out during placement to ensure a perfect future behavior

This list is not limitative and the contractor may add any other information he considers for the support of his product. Furthermore, the Owner may request any detail he considers necessary.

VII-A-7 PHYSICAL PROTECTION OF THE MEMBRANE COMPLEX

Contractor to differentiate between the upper protection, which is necessary to complement the membrane to withstand all the external weather agents and waves, and the physical protection which has the role to protect the membrane against the vandalism. The upper protection cost is considered included in the unit rate of membrane complex, while the physical protection will be paid separately (in case of necessity) and is to be installed in locations defined by the Engineer.

In case of a membrane complex with an upper protection, that at the same time can replace the physical protection, the upper protection is subject to fulfill all the requirements of the physical protection.

The physical protection system of the membrane complex at the bottom of the reservoir, should be as defined in the tender documents. It consists of a 50cm thickness fill. Used material should be defined by the Contractor taking into account the circulation of trucks on the surface. The payment for this item will be based on the volume of executed fill, while the payment of the upper membrane protection (geotextile or similar) is considered included in the unit rate of the geomembrane complex item.

Concerning the physical protection on the slopes (reservoir slopes and berms and dam slopes), it is left to the Contractor to define it, in his method statement to be submitted prior to start the execution.

While the main purpose of the protection system is to protect the membrane complex against vandalism, it should be able to withstand also all the external agents mentioned above and related to the membrane complex (winds (up to 160km/h), UV, waves (50cm), harsh weather of the area, slopes conditions,…). The selection of this system should take into consideration the type of the selected membrane complex as defined by the Contractor himself. This selection should be justified by the Contractor based on previous experience and realized similar projects with success. Furthermore, the required life span of any proposed physical protection should be at least equal to the life span of the geomembrane complex.

The method statement should also include the details of this system in addition to the stability details. Anchorage of the physical protection to the foundation (through the membrane) will be advantageous.

For indicative purpose, this physical protection system can be reinforced concrete slabs, earth retaining geocomposite,… however, the Contractor can propose his own system based on the waterproofing complex proposed by himself and to fulfill all the requirements of the protection of the waterproofing complex.

In case of a selection of a protection system consisting of earth retaining geocomposite system, attention of the bidder is drawn to the necessity to retain significant thickness of topsoil or granular materials on slopes that is also suited for erosion control. This earth retaining geocomposite should be valid to be used on slopes of the exiting upstream face of the dam as well as the reservoir slopes.

- The Defect Insurance should include also this system

VII-A-8 WARRANTY PERIOD

Two warranties are considered:

- The first one is related to the perfect efficiency of the waterproofing system installed. It is supported by a retention of 10% of the total payment until the filling of the reservoir, provided it is achieved within 2 years after completion of the works. In case the reservoir is not completely full during this period and of a satisfactory watertightness of the membrane, the remaining 10% will be released.

- Defect insurance (10 years) to be provided by the Contractor at the contract signature, starting at the completion of works. It should cover any defect in any element of the membrane complex or in its physical external protection. It shall consist of a Professional Liability Insurance released by an international reputable insurance company with a local leader or branch. This insurance should cover all type of defects that can occur during the ten years following the completion of works. The maximum coverage of this insurance should be one Million Dollar.

Furthermore, the Contractor should commit himself to carry out any defect that may appear after the first total impounding of the reservoir. To this end, he should provide a spare additional surface of 500 m² of the membrane to be stored on the site to be used for any required repair work.