

**OMAN WASTEWATER
SERVICES COMPANY S.A.O.C**



**الشركة العمانية
لخدمات الصرف الصحي ش.م.ع.م**

OMAN WASTEWATER SERVICES COMPANY

TECHNICAL STANDARD SPECIFICATION

CIVIL WORKS

SECTION 03 CONCRETE WORKS

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SECTION 03 CONCRETE WORKS

1. General

This Section includes the requirements for concrete work for pipelines, Roadwork, runways, structures, water retaining structures, foundations and bases for structures and equipment.

2. Materials

2.1 Aggregates

Fine and coarse aggregates for concrete shall comply with BS EN 12620:2002 Notwithstanding such compliance, the nature and particle shape of the aggregate must be such as to ensure that:

- a) The necessary strength and workability requirements can be met.
- b) The Flakiness and Elongation indicates of the predominant size fraction in each single sized coarse aggregate, determined in accordance with BS 812, shall not exceed 20% and 35% by weight respectively
- c) The fine aggregate shall consist of clean sand and be within Zone 2 and Zone 3 grading as defined in BS EN 12620:2002.
- d) The coarse aggregate shall, consist of crushed or natural gravel or single or of crushed limestone , to the Engineer's approval.
- e) Aggregates shall not contain any deleterious matter either in any form or sufficient quantity such as to adversely affect the strength and durability of the concrete. In particular, the following shall apply:

The sodium chloride content of the aggregate shall not exceed the following percentage of the dry weight of the aggregates:

Fine aggregate	0.08%
Coarse aggregate	0.04%

If the content of either aggregate exceeds these limits the material shall still be considered acceptable provided that the total sodium chloride of the aggregates does not exceed 0.32% by weight of the cement in the mix.

The maximum sulphate content expressed as SO₃ (sulphur trioxide) shall not exceed 0.25% of the dry weight of the aggregate, or it shall be such that the maximum sulphate content does no more than double the sulphate content already in the mix and which is attributable to the sulphate (gypsum) content of the cement.

The allowable shell content, expressed as a percentage by weight of dry aggregate, as calcium carbonate shall not exceed the following: -

Table 3.1

Nominal Size of Aggregate	Total	Hollow
40 mm	6.0 %	1.0 %
20 mm	6.0 %	1.0 %
Fine	15.0 %	2.0 %

The Contractor shall satisfy the Engineer that the proposed aggregate is compatible with the cement and that its use will not give rise to a chemical reaction between the alkali in the cement and the aggregate which would affect the durability of the concrete.

The Contractor shall supply to the Engineer for approval full details of the aggregate he proposes using prior to any concrete being placed in the works. Such information shall at least include the source of each aggregate, current certificate of grading of the aggregate, test certificates covering sulphate, chloride and shell contents and alkali / aggregate relationship prior to any concrete being placed in the works.

Consequently during the course of the contract, further grading and test certificates shall be supplied to the Engineer at approximately monthly intervals, or at such longer intervals as the Engineer may direct. The costs of all testing shall be allowed for by the Contractor.

The source of aggregate shall not be changed without the approval of the Engineer.

The aggregate shall be stored on a concrete slab to prevent contamination and inter-mixing of different aggregates. The aggregates shall be kept cool by shading the stockpiles from the sun or by sprinkling them with water so that cooling results from evaporation.

2.2 Cement

2.2.1 GENERAL

This Part covers the requirements for the testing and use of cement in structural concrete. The type of cement to be incorporated into the concrete shall be indicated on the drawings and shall be one of the following types complying with the appropriate British Standard:

Ordinary Portland Cement
Sulphate Resisting Cement

Prolonged storage of cement on site is to be avoided and any cement stored on site for a period greater than 21 days shall be liable to rejection by the Engineer and, if so directed, the Contractor shall remove such cement from site at his own expense.

Any bag or package or sample of cement which has been damaged, or re-bagged or in any way has deteriorated shall be rejected either as an individual bag or package or as the whole consignment in which such bag, package or sample is contained.

The Contractor shall keep records of the various consignments of cement in store, giving quantities received and used, and the sections of the work in which the cement has been used, on a weekly basis and make a weekly return to the Engineer accordingly.

At the time any cement is used in the works it shall be free from lumps.

2.2.2 Relevant Standard

BS 12, Portland cement
BS EN 197-4:2004, Portland-blast furnace cement
BS 4027, Sulphate-resisting Portland cement
BS 4550, Methods of testing cement

2.2.3 Approved Source

The Cement shall be obtained from an approved source, which shall not be changed without the Engineer's approval. The manufacturer's test certificates shall accompany every delivery of cement. If such certificates are not available, the contractor shall take representative samples from different bags or containers of each consignment, which then shall be packed and labeled and sent for testing to an approved testing laboratory for compliance with BS12 or BS 4027, as appropriate, at the Contractor's expenses.

For each variety of cement, separate storage shall be provided and contamination of one type by another shall be scrupulously avoided.

2.2.4 Sampling

The methods of obtaining samples of cement for testing shall be carried out as described in BS 4550 Part 1

The Contractor shall provide samples from each consignment of cement delivered to the Site, or as required by the Engineer. Fourteen days shall be allowed for the Engineer's review of these samples or otherwise as stated in the Contract.

2.2.5 Delivery, Storage and Handling

All cement delivered to site shall be delivered in approved containers, protected from contamination during transit and stored in an approved silo or silos or in weatherproof sheds each large enough to allow proper separation between different consignments. The storage shall also be arranged so that the cement is used in the order in which it was delivered and in such a way that the Engineer can readily identify any particular consignment for sampling and testing purposes. The floor of the shed shall be raised clear above the surrounding ground by at least 250 mm and any cement, which becomes contaminated, shall be removed from the site.

The Contractor shall provide weighing machines which shall be kept permanently in each shed for checking the weight of the bags or barrels of cement. The weighing machines shall be calibrated by an independent agency. The Engineer shall have access at all times to the cement storage sheds

During transport and storage the cement shall be fully protected from all weather elements.

Any consignment of cement not used within two months from the date of manufacture and cement which in the opinion of the Engineer is of doubtful quality shall not be used in the Works until it has been retested and test result sheets showing that it complies in all respects with the specification and relevant standards.

2.3 Reinforcement

2.3.1 Source of Reinforcement

The source of the reinforcement shall be subject to the approval of the Engineer. All reinforcement shall comply with BS 4449:2005. If approval of reinforcement not complying with the British Standard is requested by the Contractor, the Contractor shall reimburse the Employer all costs incurred by the Engineer or his representative in carrying out such checks or tests as he requires to be done before approval can be given.

2.3.2 Bending Dimensions and Scheduling

The Contractor shall provide facilities on site for the accurate cutting and bending of reinforcement in accordance with BS 8666:2000

Where fabric reinforcement is to be bent the requirements will be indicated on the drawings. The fabric shall be bent to the indicated dimensions and wherever possible the Contractor shall position the bends so as to avoid welded transverse wires occurring within four diameters of the start of a bend. Where high tensile steel is specified the Contractor may use either hot rolled high yield ribbed bars or cold worked deformed bars. The Contractor shall order and use one type only.

Mild steel shall not be substituted for high tensile or vice versa.

2.3.3 Labeling and Storage

All bars or bundles of bars shall have a waterproof label securely attached stated the drawing number and bar mark.

Reinforcement shall be stored in a manner and place such that it is kept free from damage and mud, oil and any contaminants likely to impair its performance within the concrete.

2.3.4 Fixing

Immediately before fixing the contractor shall ensure that all bars are free from scale, loose rust or any other matter which is likely to impair the bond with the concrete and where necessary shall remove those using appropriate means.

Bars, which are damaged, shall not be used in the works. Any bars, which become damaged after fixing shall be removed, and a replacement bar fixed in its position.

The Contractor shall securely fix the reinforcement in the positions indicated on the drawings and shall be responsible for maintaining it in this position until the concrete has hardened.

The contractor shall provide sufficient support, by means of approved chairs, spacers and any other means to ensure that all reinforcement is held in the correct positions whilst concreting is taking place. Reinforcement shall be rigidly bound together at every intersection of two bars by 1.6-mm soft annealed iron wire binding. All starter bars shall be set in position prior to concreting and securely held during concreting. The specified covers shall be maintained by use of concrete spacer blocks securely fixed to the bars. Concrete space blocks shall be made from materials in no way inferior to those specified for the concrete in which the spacer block is to be used.

Plastic spacers may be used with if approved by the Engineer.

Welding of rod reinforcement will not be permitted.

Bends in cold-worked high tensile steel shall not be re-worked in any manner.

In some instances bends in hot-rolled tensile steel may be straightened or reworked with the application of heat. Such work must not be carried out except with the consent of the Engineer.

2.3.5 Surface Condition of Reinforcement

Immediately prior to concrete placing the reinforcing steel shall be washed thoroughly with potable water to remove any deposited salts.

Reinforcement shall be free from rust, oil, grease and other deleterious matter. Grit blasting shall not be used for this prepping process. All reinforcement shall be approved by the Engineer.

2.3.6 Welding of Reinforcement

Following the establishment of a satisfactory welding procedure, each welder to be employed on the Works shall carry out welder performance qualification tests on reinforcing bars of the same metal and size as those on the Works. The requirements of ASME Code Clause IX of 1959 shall be observed.

Reinforcing which is specified to be welded shall be welded by any process which the Contractor can demonstrate by bend and tensile tests will ensure that the strength of the parent metal is not reduced and that the weld possesses a strength not less than that of the

parent metal. The welding procedure established by successful test welds shall be maintained and no departure from this procedure shall be permitted.

2.3.7 Permitted Tolerances

Without affecting in any way the Contractor's responsibility for the fit of the reinforcement, the position of the reinforcement, or the dimensions of the finished concrete, the cover to tolerance may vary in accordance with table 3.2.

Table 3.2

Concrete Cover mm	Permitted Tolerance mm
25 mm	+5mm
From 25 mm to 55 mm	-5mm TO +5mm
Greater than 55 mm	-5mm TO +10mm

2.3.8 Testing

The Contractor shall supply relevant rolling mill test certificates before any reinforcement is used.

Periodic testing of all reinforcement used on site will be required and will comprise:

- a) Tensile tests
- b) Bend tests
- c) Re-bend tests

The number of periodic tests will depend upon the total weight of steel used on site and shall be in accordance with the followings: -

Up to 50 tones – One test at the start of the works.

50 to 100 tones – One test at the start of the works and one other.

Over 100 tones – One test at the start of the works and one test for each 100 tones (i.e. for 460 tones – initial test plus 4 tests).

The periodic tests shall be spaced out over the duration of the works as directed by the Engineer. Each time periodic testing is carried out a set of six test pieces of each diameter and each type of bar delivered to site will be required. The length of each test piece shall be the greater of twenty times the nominal bar size or 600 mm.

From each set of six pieces, two pieces will be used for tensile tests, two for bend tests and two for re-bend test. For each type of test the two pieces shall be taken from different bars.

Tests and results shall comply with the requirements of the appropriate British standards as follows: -

Cold worked steel bars BS 4461: 1978

Hot rolled steel bars BS 4449: 2005

Test results shall be collected together and dispatched without delay to the Engineer. In the event of a sample failing a test the batch represented by that sample shall be rejected.

The Contractor may be permitted to carry out, at his own expense, such additional tests as required by the Engineer to establish that the material is complying with the relevant British Standard and that the rejection could be removed.

2.4 Water

2.4.1 General

This part covers the use of water for Concrete mixes and curing.

2.4.2 Relevant Standards

BS 1377 Methods of test for soils for Civil Engineering Purposes.

BS 3148 Water for making concrete.

BS 2690 Method of testing water used in industry.

BS 4550 Test for setting timer.

2.4.3 Quality of Water

Mixing water for concrete and for spraying aggregates and shutters, for curing and like purposes shall be from a source approved by the Engineer. The water shall be clean, fresh, and free from oil, organic matter and other deleterious substances.

Prior to the commencement of concreting and subsequently once every three months the Contractor shall sample and test the water supply for the presence of sulphate and

chloride salts. The amounts of dissolved solids in the water shall also be checked on a weekly basis by conductivity method during the period which concrete work is being carried out, and any significant change in the amount of dissolved solids recorded shall be immediately investigated by further testing for sulphate and chloride salts.

Water for concreting shall not contain more than 1000 parts per million of sulphate (SO₃) nor more than 500 parts per million of chlorides.

If at any time when tested with Universal indicator the water supply has a pH value outside the limits of 5.5 to 8.5 then the Engineer shall be informed and the Water shall be tested in accordance with the recommendations of BS EN 1008:2002 in order to determine the acceptability of the supply for further use. In the interpretation of the test results the Engineer's decision shall be final. Water shall be potable and shall comply with the requirements of BS EN 1008:2002.

Water Temperature shall not be less than 5 °C and not more than 25 °C. Water may be cooled by means of chillers or the addition of Ice particles.

3. Admixtures

Admixtures shall mean materials added to the concrete materials during mixing for the purpose of altering the properties of the concrete mix. In addition to the specified general requirements for approval of materials, approval of admixtures shall be subject to extensive trials to demonstrate the suitability, adequacy of dosing arrangements and performance.

Approval of admixtures shall be subject to extensive trials to demonstrate the suitability, adequacy of dosing arrangements and performance. Where approved and or directed by the Engineer, admixtures shall be used as a means of:

- (a) Improving concrete durability
- (b) Improving workability of the concrete without increasing the w/c ratio
- (c) Controlling and limiting retardation and setting.

The methods of use and the quantities of admixture used shall be in accordance with the Manufacturer's instruction and subject to the Engineer's approval after evaluation in trial mixes and shall in no way limit the Contractor's obligations under the Contract to produce concrete with the specified strength, workability and durability. The effects of accidental overdose of the admixture and measure to be taken if an overdose occurs shall be provided by the Contractor to the Engineer. No admixtures containing chlorides shall be used. In particular, the use of acceleration admixtures containing calcium chloride shall not be used.

4. Mix Design

At the start of the construction period, the Contractor shall design a mix for each grade of concrete listed in Table 3.3 or any other grades described in the contract document that is required to be built into the Works or otherwise required for particular Contract.

For concrete using other than ordinary Portland cement or incorporating admixtures, the strengths shall not be less than those specified in Table 3.3, but the mix designs shall be revised and agreed with the Engineer.

Table 3.3

Grades of Concrete

Concrete Grade	Max. Size Aggregate mm	Min. Cement Content kg/m ³ Type of Cement OPC	Max. Free Water: Cement Ratio	Cube Crushing at 28 d	
				Trial Mix Test MPa	Works Test MPa
40/20	20	380	0.4-0.45	50	40
35/20	20	350	0.4-0.45	45	35
30/20	20	330	0.4-0.45	40	30
25/20	20	320	0.45-0.50	35	25
20/20	20	310	0.55	30	20
15/20	20	280	0.55	25	15

The concrete mixes to be used in each section of the work shall be designed to give a guaranteed minimum strength which shall be referred to by a number which denotes the nominal crushing strength in Newtons per square millimeter which must be obtained from any 150 mm cube tested at 28 days together with a number to show the maximum aggregate size to be used.

For each specified mix, the concrete shall be such that it has the lowest cement content and maximum practical size of aggregate which are necessary to attain the required crushing strength and workability with minimum water/cement ratio in order to ensure full compaction when used under the conditions that will be encountered in the work, provided that the cement content, and where shown the free water/cement ration, are within the limits given in Table 3.3

The aggregate size to be used is added to the mix reference, e.g. Mix 25S/20 indicates 25 N/mm² concrete with sulphate resisting cement with 20 mm maximum sized aggregate.

The mixes shall be designed by the contractor and, before any concreting is commenced, details of the mixes must be submitted, preliminary samples of the mixes prepared and 28 days test results obtained for approval by the Engineer before any concrete is placed in the works.

The 28 day strength of trial mixes prepared in a laboratory shall be one-third greater than the required works 28 day strength

5. Trial Mixes

As soon as the Engineer has approved the concrete mix design for each grade of concrete and during or following the carrying out of the preliminary tests, the Contractor shall prepare a trial mix of each grade in the presence of the Engineer at least 35 days before commencement of concreting.

Where ready mix concrete is being used, the above requirement may be waived at the discretion of the Engineer if the Contractor has documented previous experience of a particular mix design with test results available.

The proportions of cement, aggregate and water shall be carefully determined by weight in accordance with the Contractor's approved mix design (or modified mix design after preliminary tests), and sieve analyses shall be made, by the method described in BS 812, of the fine aggregate and of each nominal size of coarse aggregate used.

The compaction factor of each batch of each trial mix shall be measured immediately after mixing by the method described in BS 1881 and shall not be less than 0.85 nor greater than 0.92. Slump test measurements shall also be taken immediately after mixing.

The Contractor shall make three separate batches for each trial mix and six 150 mm compression test cubes shall be made from each batch in the presence of the Engineer. Three cubes shall be tested at 7 d and 3 at 28 d, after manufacture in accordance with the method described in BS 1881. The value of the strength of the nine cubes tested at 28 shall meet the requirement of strength given in Table 3.3.

Additionally, the Contractor shall measure the temperature, workability and density of concrete in each batch

A full scale test of the workability of each trial mix of each grade of concrete shall be made by the Contractor in the presence of the Engineer. The trial mix of each grade of concrete shall be batched, mixed and then transported a representative distance in the manner that the Contractor proposes to batch, mix and transport the concrete to be placed in the Works. After discarding the first batch so made, the concrete from later batches shall be placed and compacted in trial moulds both for reinforced and mass concrete with dimensions typical of the Works.

The sides of the moulds shall be capable of being stripped without undue disturbance of the concrete placed therein. The sides of the moulds shall be stripped after the concrete has set and the workability judged on the compaction obtained. If the workability test shows that the workability required is not attained for any trial mix for any class of concrete, the trial mix shall be redesigned by the Contractor and a further full scale workability test shall be undertaken for that trial mix of concrete.

Redesign of the concrete mixes and the making and testing of preliminary and trial mixes of concrete shall be repeated for each grade of concrete until trial mixes of concrete meeting the requirements of the Table 3.3 and having the workability required to place it in the Works, as demonstrated in the full scale workability test described above, have been established.

The Contractor shall use only the approved mix of each grade of concrete in the Works. If at any time during the construction of the Works the source of cement or aggregate is changed or the grading of the aggregate alters to such an extent that the fraction of aggregate retained on any sieve cannot be maintained within two percent of the total quantity of fine and coarse aggregate when adjusted in accordance with this Clause, then further trial mixes of concrete shall be made, tested and approved for use.

Preliminary laboratory tests shall be carried out to determine the mixes to satisfy the specification with the approved materials. Trial mixes shall be tested to determine the following properties of mixes proposed for initial field tests:

- a) bleeding in accordance with ASTM C232 (non-vibrating) shall not exceed 0.5 %.
- b) drying shrinkage in accordance with BS 1881 Part 5 or BS 6073 Part 1, Appendix D (c) air content to BS 1881 Part 106.
- c) Free water: cement ratio.
- d) Workability to BS 1881 Part 102.

- e) Fresh and hardened concrete densities to BS 1881 Parts 107 and 114, respectively.
- f) Compressive strength to BS 1881 Part 116.

If the values obtained are unacceptable, the mixes shall be redesigned.

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 of this Specification

The Engineer may also require practical tests to be made on the Site by filling trial moulds to confirm the suitability of:

- a) Mix for the works
- b) Type of plant used for mixing
- c) Face intended for use in the works
- d) Type of form oil
- e) Type of protective coatings.

All costs connected with the preparations of trial mixes and the design of the job mixes shall be borne by the Contractor.

Whenever a change of brand or source for any of the concrete ingredients occurs, additional "preliminary tests" will be required.

6. Cubes Strength

In order to ensure that the quality of materials and mix proportions are maintained throughout concreting operations, sampling and testing shall be carried out using the relevant procedures set out in BS 812, BS EN 12620:2002 and BS 1881 and all other relevant codes quoted in this specification in accordance with a routine testing program that shall be agreed with the Engineer before the start of concrete work.

All testing specified shall be carried out at an independent testing Lab approved by the Engineer, and immediately following the letting of the Contract, the contractor shall submit for approval all the lab details.

Certificate copies of all test certificates and reports prepared by the Tester shall be submitted direct to the Engineer Preparation and sampling of concrete shall be in accordance with the requirements of BS 1881.

The Contractor shall submit to the Engineer for approval the proposed mix design and cube test results tested as per BS 1881. The cost of making and testing these cubes shall be borne by the Contractor and shall be deemed to be included in his price.

Where ready-mixed concrete is used in the Works, the procedure for taking cubes as laid down in this clause shall be followed regardless of the supplier's own testing routine. Test certificates of the supplier's test cubes shall be submitted to the Engineer.

The design mix with admixtures, if any, together with test certificates of suppliers test cubes shall be submitted to the Engineer for prior approval.

The number of cubes taken of the concrete used in the Works will be six per 120 cubic meters of mass concrete, six per 60 cubic meters of reinforced concrete, and in very large pours, such as large reinforced rafts, six cubes per 30 cubic meters. Of each set of six cubes three cubes shall be tested at seven days, another at 28 days.

7. Workability

The workability of fresh concrete shall be suitable for the conditions of handling and placing so that after compaction concrete surrounds all the reinforcement and completely fills the formwork without voids or honeycombing. The design slump range of the concrete shall be the minimum necessary to ensure the correct placement and compaction of the mix.

The design slump range shall be between 50 mm and 100 mm. For difficult placements with congested reinforcement the Engineer may permit the formulation of a mix design with a design slump up to 150 mm. Such permission shall be in writing and shall identify the specific placing conditions.

The slump test shall be carried out in accordance with BS 1881. Sampling of concrete for the slump test shall be carried out in accordance with BS 1881 when sampling from a mixer truck.

The Contractor shall arrange for the concrete to be tested for slump just prior to placing at the site. The first truck of the pour shall be tested to verify the workability and thereafter for every hour of production or every 30 m³. Slump values shall be written on the delivery ticket with the time taken.

In the event of high variability of slump values, the Engineer may instruct that each truck of concrete is checked for slump at the plant. The Contractor shall carry out an investigation to establish the cause of the high variation in slump and shall take any necessary corrective action.

8. Batching and Mixing

8.1 Relevant Standard

BS 1881, Methods of testing concrete
BS 5328, BS EN 206-1:2000, BS 8500.

8.2 Mixing

All mixing carried out on site will be by power driven batch machines having an accurately calibrated device for the delivery of water and approved size and type manufactured in accordance with BS 1305, and tested in accordance with BS 3963.

The weighing and dispensing mechanisms shall be maintained in good order throughout the contract. Their accuracy shall be within the tolerance described in BS 1305 and checked against accurate weights and volumes. The mixer shall be properly maintained in accordance with the manufacturer's recommendations.

All constituents shall be batched by weight. The weight of the fine and coarse aggregates shall be adjusted to allow for the free water content in them.

The quantity of water added to the mix shall be adjusted to allow for the free water contained in the aggregate.

Cement supplied in bags shall be placed directly from the bag into the intake of the mixing plant and each batch must contain one or more complete bags of cement. No mixer having rated capacity of less than one-bag batch shall be used and the mixer shall not be charged in excess of its rated capacity.

The materials shall be mixed to an even colour and consistency. The period of mixing shall be kept to a minimum consistent with achieving satisfactory quality but not be less than 1.5 minutes. Prolonged mixing must be avoided. The mixer shall be operated at the manufacturer's recommended speed.

Mixing plant that has been out of action for more than 30 minutes shall be thoroughly cleaned before any fresh concrete is mixed in it. The first batch of concrete materials through the mixer shall contain an excess of cement to coat the inside of the mixing drum without reducing the required mortar content of the mix. When a change of mix is made to one using a different type of cement, the mixing plant shall be thoroughly cleaned of all traces of the previously used cement, whatever the time interval between successive mixes.

During hot weather the contractor shall take steps to reduce the concrete temperature by spraying the aggregates with water, shading the materials and mixer plant or any other protection measures may be directed by the Engineer.

8.3 Ready mixed Concrete

Ready-mixed concrete shall not be used unless approved, and shall comply with the requirements specified herein and those of BS 5328 and the Quality System for Ready Mixed Concrete (QSRMC) Technical Regulation. Ready-mixed concrete, plants and mixer trucks shall be subject to approval.

Ready mixed concrete batched off site shall only be used with the written approval of the Engineer, who will lay down additional conditions.

9. Transportation and Placing of Concrete

Transportation delivery and handling shall be in accordance with the requirements of BS 5328 Part 3.

Concrete shall be conveyed from the mixer to its place in the works as rapidly as possible by methods which will prevent segregation or drying out and ensure that the concrete is of the required workability at the point and time of placing. The Contractor shall ensure that the time between placing of different lifts or layers of concrete is short enough to prevent the formation of cold joints. The Contractor shall ensure that there is a back up plant that can be used in the event of a breakdown, and that adequate provision has been made for the number of delivery trucks.

The concrete shall be transported to the site in an approved type of truck mixer or agitator truck. The discharge chute shall be washed down after delivery to prevent spillage on the roads.

The insides of concrete mix trucks shall be inspected periodically and any build up of concrete that may impair the efficiency of the mixing action shall be removed. Concrete shall be handled from the place of mixing to its place in the Works within 60 min unless retarders have been incorporated in the mix that have satisfactorily demonstrated that workability and other properties can be retained, and that approval is obtained in writing from the Engineer.

10. Pumped Concrete

Mix design details for pumped concrete must be submitted to the Engineer a minimum of 14 days before it is proposed to use the pump mix.

Cement slurry shall be pumped through the concrete pump to provide initial lubrication. The first 0.25 cubic meters of concrete passing through the pump at the start of each pour shall not be incorporated in the works.

Access for the pump shall be checked prior to the pour. If access cannot be assured, the Contractor shall not continue with concreting operations by pump.

Where concrete is conveyed by chuting or pumping the plant shall be of a size and design to ensure continuous flow in the chute or pipe. The slope of the chute or the pressure of the pump shall allow the concrete to flow without the use of any water additional to that approved by the Engineer to produce the required consistency and without segregation of the ingredients. The delivery end of the chute or pipe shall be thoroughly flushed with water before and after each working period and kept clean. The water used for this purpose shall be discharged outside and away from any permanent works.

The free fall height of pumped or chuted concrete shall not exceed 2.0 meters

11. Formwork

11.1 General

Formwork shall include all temporary or permanent moulds for forming the concrete, together with all temporary construction required for their support. The contractor shall be entirely responsible for the sufficiency of the formwork and shall submit detailed formwork drawings for approval. The drawings submitted shall show all general fixing and support details. The Engineer's approval does not absolve the contractor of his responsibility. All timber used for forms, false work and centering shall be sound wood, well seasoned and free from loose knots, shakes, large cracks, warping and other defects. The formwork shall be so designed and constructed that the concrete can be properly placed and thoroughly compacted.

All form work whether metal or timber shall be securely placed and supported to prevent sagging. All joints are to be closed to prevent leakage of liquid from the concrete, with special care being taken where vibration of concrete will take place. Formwork panels shall have true edges to permit accurate alignments at sides and to provide a clean line at construction joints in the concrete.

Formwork shall be so designed that no damage to the concrete shall occur when the formwork is removed. It shall be constructed such that the formwork to the sides of members can be removed without disturbing the soffit formwork or its supports. Props and supports shall be designed to allow the form work to be adjusted accurately to line and level, and due allowance shall be made for any settlement or deflection of the form work that may arise during construction so that the hardened concrete conforms to the specified line and level.

Formwork shall be treated on those surfaces against which the concrete is to be poured with approved formwork release agent. To facilitate the removal of dirt, debris, etc wash out holes is to be left where access is difficult.

The responsibility of the removal of the form work shall rest with the Contractor, and in no circumstances shall the form work be removed until the concrete has reached adequate strength to resist damage. The minimum time that must elapse between casting of the concrete and removal of form work is given only for the Contractor's guidance as follows:

Wall, columns, beams, slides – 05 days
Soffits of slabs (props) – 10 days
Soffits of beams (props) – 14 days

Formwork shall be removed without shock or vibration, which may damage the concrete. Formwork, which is to be re-used, must have its surfaces scraped smooth and clean and be re-dressed. Where concrete is to form a finished surface spacers used for positioning reinforcement are to be of the same mix as that used in the concrete so as to present a uniform appearance. All exposed concrete corners are to have 25 x 25 mm chamfers unless specified otherwise.

11.2 Ties

The Contractor shall submit to the Engineer for approval details of any ties or cast in fixings that he proposes to use in connection with his formwork. Any embedded metal ties shall not have any part of the tie closer to the finished concrete surface than the specified thickness of cover to the reinforcement. Holes left after removal of any ties shall be filled with an approved mortar.

11.3 Built in -fixings and Sundry Items

The Contractor shall be responsible for accurately casting in the concrete work or fixing to the formwork any fixings, ties, dowels, slots, holding down bolts, etc required for securing blockwork, precast concrete work, steelwork or electrical and mechanical services for other trades and suppliers.

Provision shall be made for forming holes, ducts, rebates, the building in of pipes, conduits and other fixings as shown on the drawings. Holding down bolts and washer plates shall be firmly set in the formwork in taper boxes, polystyrene blocks or other approved sleeves as shown on the drawings.

After concreting, but before the concrete has set, the bolts shall be turned and loosened so that they are free to move in the finished work.

Except where shown on the drawings, no fixtures shall be attached to the concrete by shot fixing or drilling without approval of the Engineer. Notwithstanding any such authorization, the Contractor shall be responsible for all damage so caused to the concrete and shall make good at his own expense.

11.4 Surface Finishes

a) Fair Faced (F1 Formwork)

Where the surface finishes are described on the drawings as 'fair faced' the Contractor shall obtain an even finish to the concrete by the use of a good quality plywood having a clean smooth impervious surface, free from all defects and with true clear arises.

The resulting concreting shall be free from honeycombing, stains, lipping nail or screw marks, raised grain marks or any other imperfections and shall be of a uniform surface texture and colour.

Only very minor surface blemishes caused by entrapped air or water will be accepted provided that they shall not be concentrated in a manner such that they are noticeable. No attempt shall be made to rub down or fill blemishes without the prior approval of the Engineer.

b) Covered Concrete Surfaces (F2 Formwork)

The formwork for all concrete, which is to be covered by render, plaster or otherwise hidden, shall be constructed in wrought board or other suitable materials. The removal of minor fins or form marks shall not be required, but all holes, cavities, and irregularities shall be made good after inspection by the Engineer and to his approval.

c) Exposed Aggregate Finish

The Contractor shall be required to produce an exposed aggregate finish of uniform appearance, free of construction and formwork joints. In addition the resulting finish shall be free from honeycombing, stains or other imperfections.

The exposed aggregate finish is to be produced by the use of concrete retarders and brush and wash techniques. The contractor shall ensure that when placing the concrete care is taken to see that the concrete is not discharged against the treated face of the formwork and that vibrators do not come into contact with the treated face. The Contractor must also ensure that close contact is maintained between the fresh concrete and the retarder.

The contractor shall provide the Engineer with details of any proposed concrete retarding agent, together with his proposed methods of application and shall obtain the Engineer's approval before the retarder is applied to the formwork.

Subject to the approval of the Engineer an exposed aggregate finish may be produced by tooling bush hammering or sand blasting but at no extra cost to the contract.

The method of forming the exposed aggregate finish shall not change during the contract without the prior approval of the Engineer.

At the start of the contract the contractor shall produce a sample panel, not less than 1.0 meter square, of the exposed aggregate finish he intends providing throughout the contract. He shall seek and obtain the Engineer's approval before any such finish is incorporated into the works.

The approved sample shall be retained on site and shall form a reference sample. The Engineer reserves the right to instruct for the removal and reinstatement, at no extra charge to the contract, of any areas of exposed aggregate finish, in the works which, in his opinion, fail to reach the standard

11.5 Tolerance for Concrete Surfaces

The tolerances of concrete surfaces shall be in accordance with the following:

Foundations and other in situ buried concrete : BS 5606

Exposed concrete : BS 5606

Floor slabs self levelling epoxy ± 4 mm

Floor slabs with concrete wearing surface with level tolerance of ± 8 mm: BS 8204 : Part 2.

Any work, which is significantly out of level or alignment, shall be liable to rejection and rebuilt at the Contractor's expense. No cutting away or making up of hardened concrete work shall be allowed without the Engineer's approval.

The Contractor shall adopt methods for setting out of the buildings which can be readily and repeatedly checked by the Engineer.

12. Grouting up of Base Plates

Where holding down bolts, base plates or other fixings are to be grouted up after erection, an approved grout shall be used to the approval of the Engineer, mixed as thickly as possible consistent with the required fluidity. It shall be poured under a suitable head and tamped until the space or voids have been completely filled. Where necessary, temporary shutter should be used to retain the grout.

Where non shrinkage grout has to be used it shall be to the approval of the Engineer and the grouting shall be in accordance with the manufacturer recommendations.

13. Curing

Curing shall comply with BS 7542 requirements

Freshly placed concrete shall be protected from sun, wind, exposure and excessive drying out and cured continuously for a minimum period of 7 days.

Covering the surface of the concrete with wet hessian and then covering the hessian with polythene to reduce evaporation should carry out curing. Additional water should be introduced when necessary to keep the hessian thoroughly and permanently wet.

Sprayed curing compounds will not normally be permitted on surfaces, which are to receive an applied finish. Where permitted they shall contain a fugitive dye to give visual indication of even and complete application. Where spray curing is permitted the Contractor shall develop a suitable QA procedure and Method Statement for its application that shall be approved by the Engineer.

Water used for curing shall be fresh well water. Where water is used for curing concrete work buried in the ground, care should be taken to avoid excessive curing water from running below the foundation of the footing.

All concrete during setting and hardening shall be protected from shock, vibration or damage from any cause. Where damage does occur, all remedial works and consequential delays shall be at the Contractor's expense.

Curing procedures shall be started immediately on completion of compaction. Protection from direct radiation and drying winds shall be in place within 30 minutes of completion of final compaction or other finishing.

14. Joints in Concrete

14.1 Intervals during Concreting

The timetable for the depositing of concrete between construction joints should be so arranged that no face of concrete shall be left for more than 20 minutes before fresh concrete is deposited against it. Pauses for meals, servicing of machines, changes of shift, etc., and the distribution of concrete among the positions where work may be proceeding simultaneously must be carefully organized to ensure that the above mentioned interval shall not be exceeded.

14.2 Construction Joints

Construction joints shall be as shown on the Drawings or as directed by the Engineer. If the Contractor wishes to make additional construction joints he shall obtain the prior approval of the Engineer. Such approval may include the provision and placing of additional reinforcement at the Contractor's expense.

Construction joints shall be formed by inserting temporary vertical stopping-off boards to form a key or as shown in the drawings. Unless otherwise shown on the Drawings construction joints shall be located as near as possible to the position of minimum tensile stress in the concrete.

At a construction joint, the face of the previously placed concrete shall be cleaned of any skin or laitance or loose material by brushing with a wire brush or other approved method and washing with clean water. Loose aggregate shall be removed. Excess water shall be removed" and the surface while still wet shall be covered with 1:2 cement mortar which must be vigorously stippled into the surface by means of a suitable stiff brush, the depositing of the fresh concrete following closely or by applying approved bonding agent..

14.3 Expansion Joints and Contraction Joints

Expansion and Contraction joints shall be constructed at positions shown on the Drawings or as directed by the Engineer and shall be formed according to the instructions and dimensions shown on the Drawings.

15 Inspection and testing

15.1 References

The following standards are referred to in this part of the specification:

BS 1881, Methods of testing concrete

BS 4408, Recommendations for non-destructive methods of test for concrete

BS 6089, Guide to assessment of concrete strength in existing structures

15.2 General

- a) The Contractor shall submit to the Engineer his quality assurance procedures for the particular parts of the testing work that will be carried out.
- b) The Contractor shall submit for the Engineer's approval the curriculum vitae (CV) of the supervisor proposed for the work.
- c) The Contractor shall prepare a report that identifies the test methods used and the test results.
- d) The report shall also identify any unusual results or relevant information relating to the testing.
- e) For each of the test results the Contractor shall identify the precision or repeatability of the particular sampling and testing method.
- f) All field and laboratory testing of concrete shall be carried out by an independent laboratory approved by the Engineer.
- g) If the 28 d works test cubes fail to meet the minimum criteria, the Engineer may direct the Contractor to carry out in situ drilling and testing to obtain concrete core results.
- h) The parts or elements of the structure made from the defective batch or batches of concrete as represented by the works test cubes shall be identified by the Engineer and based on this information the Engineer shall instruct the Contractor on the required number and position of concrete cores.
- i) The Engineer shall review the concrete core test results in conjunction with BS 6089
- j) Based on this assessment the Engineer shall decide the acceptability of the concrete in the structural element and may either:
 - accept the concrete
 - instruct that certain remedial works should be carried out
 - instruct that the element is replaced

16. Protective Coating of Concrete

16.1 General

This Part covers the materials and application requirements for coatings for concrete. The Contractor shall submit manufacturers' specifications, installation instructions and other data to show compliance with the requirements of this part of the specification and the Contract Documents. The Contractor shall submit samples of all materials to be used

in the works before delivery of material to Site. The Contractor shall submit comprehensive test results for the protective coating system.

Protective coating shall be applied where designated in the contract specific documentation. All protective coating systems to be used shall be applied strictly in accordance with the manufacturers recommendations.

The Contractor shall take all necessary precautions against fire and other hazards during delivery, storage and installation of flammable materials specified herein and to comply with Omani occupational Health and Safety regulations.

16.2 Surface Preparation

- a) Before application, all surfaces must be dry and free from oil, grease, loose particles, decayed matter, moss or algae growth and general curing compounds.
- b) All such contamination and laitance must be removed by the use of grit blasting, high pressure water jetting or equivalent mechanical means.
- c) Blow holes and areas of pitting shall be made good with an approved material and allowed to cure in accordance with the manufacturer's recommendations.
- d) In particular, the application shall be in accordance with the manufacturer's recommendations, with respect to the maximum application thickness.

16.3 PVC Lining

The material used in manufacturing the liner and all joint, corner and welding strips shall be a combination of polyvinylchloride resin, pigments and plasticizers, specially compounded to retain flexibility. Polyvinyl chloride resin shall constitute at least 99 percent by weight of the resin used in the formulation. Copolymer resins will not be permitted.

- a. Tensile specimens shall be prepared and tested in accordance with ASTM D412 Weight change specimens shall be 25 mm by 75 mm sample of the sheet thickness. Specimens may be taken from sheet and strip at any time before final acceptance of the work.
- b. Liner plate locking extensions embedded in concrete shall withstand a test pull of at least 1790 kg per meter applied perpendicularly to the concrete surface for a period of one minute, without rupture of the locking extensions or withdrawal from embedment. This test shall be made at a temperature between 21 degrees to 27 degrees C inclusive.

- c. All plastic liner plate sheets including locking extensions, all joint, corner and welding strips, shall be free of cracks, cleavages or other defects adversely affecting the protective characteristics of the material. The Engineer may authorize the repair of such defects by approved methods.
- d. The lining shall have good impact resistance, be flexible and have an elongation sufficient to bridge up to 6 mm wide settling cracks which may occur after installation, without damage to the lining.
- e. The lining shall be capable of being repaired at any time during the life of the structure.

16.4 GRP Linings

The waterproof liner shall consist of a minimum thickness of 7 mm glass reinforced plastic (GRP) laminate. The GRP laminate liner shall be composed of a 4 mm thickness layer of minimum 29 percent "E" glass to a maximum 71 percent resin content base layer, and a resin rich 2 mm thick outer layer (layer in contact with liquid) consisting of an approved vinyl ester resin with at least two layers of "C" glass veil meeting 90 percent resin to 10 percent "C" glass ratio by weight.

The GRP liner shall be shaped to match the required dimensions and configurations, as shown on the drawings, and installed in Clauses, as required for proper concrete placement and GRP field jointing techniques. Each GRP liner shall also be equipped with pre-molded pipe openings, such that proper bonding can be obtained between the GRP liner and the pipe as otherwise specified, and as shown on the drawings. All field bonded GRP joints shall meet the minimum requirements of the liner and be installed such that the bond is watertight and no loss of strength occurs through the joint. Field applied joint strips shall be a minimum 100 mm wide, 6 mm thick, laminate consisting of 71 percent vinyl ester resin content to 29 percent "E" glass.

On the internal faces of manholes or other sewage retaining structures the joint strips shall be applied to the concrete side of the GRP liner. Immediately before taking over by the Employer and after inspection for leakage an additional joint strip shall be fixed on the internal face of the GRP liner.

Prefabricated GRP liners shall have bonding lugs (concrete anchors) consisting of 100 mm long GRP strips or GRP round studs, bonded to the concrete adjacent face of each GRP panel, not to exceed 500 mm x 500 mm approximate spacings.

The shape of each bonding lug shall be such to produce a secure bond in the cast-in-situ concrete such that the GRP liner is held firmly in place, in contact with the concrete surface, alleviating any tendency of the liner to become unbonded and "float" away from the concrete.

The prefabricated GRP liner shall be adequately braced and carefully handled such that excessive deflections, breaking, or cracking of the liner does not occur during handling, installing and pouring concrete.

A non-slip finish shall be placed on horizontal benching surfaces, platforms and step points by dusting the surface of the laminate with silica sand as soon as the resin has set to a soft gel. Surplus sand shall then be brushed no less than 24 hours later.

17. Hot Weather Concreting

Concrete shall not be mixed or placed when the shade air temperature on site is 40°C or above unless the contractor has demonstrated special measures to ensure that the concrete is satisfactorily placed, compacted and cured. The temperature of the fresh concrete shall not exceed 32°C unless evidence is provided that at a higher temperature for the in-situ concrete strength and durability will not be compromised.

Reinforcement shall be kept in the shade for a minimum period of 4 hours before concreting. Any formwork made of metal, concrete or other material of high thermal capacity shall be cooled with water before concrete is placed against it. Only water meeting the requirements for mix water shall be used for washing and cooling forms, etc.

18. Water Retaining Structures

Water Retaining Construction shall prevent water from passing through the concrete from one side to the other. This will be considered to have been achieved if no running water, water droplets or damp staining occurs on one side of the concrete when the other side is subjected to water pressure up to the designed head of water.

The specification clauses listed hereunder are to be read in conjunction with and shall prevail over those of the section in the specification for concrete work for concrete for water retaining structures.

The aggregates shall be gravel natural sand both in accordance with BS EN 12620:2002 and having a low drying shrinkage and absorption not greater than 3% measured in accordance with BS 812.

The grading sand shape shall be such as to produce a concrete which with the specified essential requirements will have a consistency suitable for the work in hand and will

readily work into position without segregating and can be readily compacted into a dense impervious mass.

18.1 Jointing

Prior to purchase and delivery of materials, submit the following and obtain the Engineer's approval:

- a) Technical data by the manufacturer of the proposed materials
- b) Manufacturer's printed preparation and application instructions

The Contractor shall accurately form recesses at expansion and contraction joints on both faces of the concrete work except on the underside of floor or ground slabs.

The Contractor shall prepare the surfaces of the recess and shall supply a joint sealant and fill or caulk the recess completely with it. One part polyurethane sealant shall be used. Over and above the sealant all expansion joints shall be sealed with a sealing strip membrane.

Sealants shall be obtained from manufacturers approved by the Engineer and shall be used in accordance with the manufacturer's instructions inclusive of the supply and application of any priming materials and debonding tapes. Joint sealing shall not be commenced without the approval of the Engineer.

The Contractor shall supply the manufacturer's test certificates for each type of joint sealant delivered to site and shall if requested supply to the Engineer sufficient samples of each type and consignment for confirmatory test to be carried out in accordance with the appropriate test procedure.

Sealant shall not be placed when the air temperature is more than 30oC

All concrete substrates shall be primed, prior to application of the sealant. The primer shall be of a specially formulated grade suitable for hot climates, one-part chemically active brush applied material. The primer shall be from the same manufacturer as the sealant.

One part polyurethane base compound for joint sealing shall comply with U.K. Agreement Board 83/1106 and shall be "gun grade" except that the application life shall not be less than 4 hours. The total curing time shall be not more than 30 days. The system shall be approved by WRC for use in contact with potable water.

The movement capacity of the sealant shall be at least 20 percent of the joint width. The final method of application shall be established by site tests to ensure that there is no

sagging. All surfaces shall be clean, dry and free from all loosely adhering particles before receiving sealant.

All joint sealants where specified shall be two part poly-sulphide sealants conforming to BS EN ISO 11600:2003 “Specification for Two Part Poly-sulphide Based Sealants”, and shall be designated as suitable for use in hot climate.

Expansion joints fillers shall be non-absorbent, semi-rigid, closed cell heat laminated polyethylene filler board or other similar material approved by the Engineer. The joint filler shall be non-tainting in accordance with BS 6920 and WRC approved or equivalent. The joint filler shall be fully compatible with the surface sealants and if elastomeric sealants are used the joint filler shall act as a bond breaker.

18.2. Waterstops

Wherever possible waterstops and associated materials shall be sourced and supplied by a single manufacturer. The manufacturer shall operate a Quality System which is registered to ISO 9001.

Shop drawings for waterstop network to be prepared by the manufacturer and approved by Engineer. Technical back-up service during application to be supplied by manufacturer on site at no extra cost.

Waterstops shall be extruded from a high grade elastomeric polyvinyl chloride compound which contains the necessary plasticizer, resins, stabilizers and other materials necessary to meet the performance requirements of this specification and shall be the ribbed type to provide better watertight sealing than dumbbells.

The waterstops shall be so designed that a fully continuous and coordinated ribbed type waterstop network to be provided throughout the structure. All waterstop intersection and transition pieces shall be factory produced molded and or prefabricated segments of the network to minimize site jointing and simplify site assembly and shall have long legs to facilitate field butt splicing when required.

The waterstops shall be WRC or equal approved for use in contact with potable water.

Before waterstop material is installed in any structure current test reports and written certificates must be submitted to the Engineer indicating that all waterstops meet the following physical properties:

a) External Waterstops

External waterstops shall be extruded from high quality polyvinyl chloride compounds, tensile strength 13.8 N/mm² elongation at break 300%. Shore A hardness 80-90, compound to be tested in accordance with BS 2782 and BS 6920.

Waterstops in base slab expansion joints shall be minimum 250mm wide with four ribs and parallel lines of fins, the height of ribs shall be 25 mm. The centre box section shall be 25mm wide and flat to accept a filler board. The waterstop shall have an outer nailing flange with a reinforced and profiled edge to resist tear when fixed to shuttering with double headed nails, and provide additional key when cast into the concrete.

Waterstops in base slab construction and contraction joints shall be minimum 250mm wide with four ribs and parallel lines of fins, the height of ribs shall be 25 mm.

The waterstop shall have an outer nailing flange with a reinforced and profiled edge to resist tear when fixed to shuttering with double headed nails, and provide additional key when cast into the concrete.

b) Internal Waterstops

All wall and roof expansion joint waterstops shall be extruded from high quality polyvinyl chloride compounds having a minimum tensile strength 13.8 N/mm², elongation at break 300%, Shore A hardness 80-90, compound to be tested in accordance with BS 2782, US Corps of Engineers specification CRD-C572-74 and BS 6920.

Waterstops in wall and roof expansion joints shall have a centre box to accommodate movement, be minimum 250mm wide with four ribs and parallel lines of fins, the height of rib shall be 25mm. The centre box section shall be flat to accept a filler board. The web shall be 10mm thick with a thickened central section to transfer stresses to the centre bulbs.

The waterstop shall have a reinforced eyeleted outer flange for secure fixing of the waterstop into position.

Waterstops in wall and roof construction and contraction joints shall be minimum 250mm wide with four ribs and parallel lines to fins. The web shall be 10mm thick with a thickened central section to transfer stresses to the centre bulbs. The waterstop shall have a reinforced eyeleted outer flange for secure fixing of the waterstop into position.

Waterstops and reinforcement shall be so arranged that there is at least 25mm clearance between them. The waterstops shall not be nailed or damaged in any way and the Contractor shall ensure that the concrete surrounding the waterstop is fully compacted without the waterstop being displaced.

18.3 Concrete for Water Retaining Structures – Workmanship

a. Placing and Compaction

Concrete shall be mechanically compacted using immersion vibrators of suitable size and in suitable numbers for the work in hand.

The concrete shall be properly compacted as described in the section of the specification for concrete work; special care being taken to ensure that.

The water stop is not moved from its proper position and is not bent over; where the water stop is horizontal it should be carefully lifted so that concrete is properly placed and compacted beneath the water stop.

The vibrator does not come into contact with the water stop.

b. Joints

Joints shall be formed at the locations shown on the drawings.

Before pouring any concrete the Contractor shall ensure that the water stop is clean and is properly fixed in position so that it is symmetrically disposed about the line of the joint. The method of fixing shall prevent the water stop from moving during the pouring and compaction of the concrete.

Any work in which the water stop is not disposed symmetrically about the joint line will be liable to rejection. The Contractor is advised that such rejection will involve demolition of the work back to the next sound joint.

The Contractor is advised that the joints must be positioned exactly according to the drawings so that the lines of the expansion joints in any special finishes are maintained over the joints in the concrete.

The surface of the concrete facing onto the joints shall be left as struck.

c. Curing

All concrete shall be maintained in a moist condition for a period of not less than 7 days from the time of casting. In hot direct sunlight horizontal surfaces shall be protected from excessive temperature rise by “ponding” or other suitable methods.

ASTM C309 approved standard product fugitive-dye resin or silicone type, free of wax or oil, compatible with subsequently applied finishes or coverings, not deleterious to bond of cementitious materials to concrete, and delivered in unopened labeled containers.

Curing shall be effected by the use of imperforate polythene sheeting of suitable thickness held in close contact with the concrete surface and securely fixed at the edge so that air cannot circulate between the concrete and the polythene. The contractor shall arrange his work so that the polythene sheeting is not removed, disturbed or damaged for the whole of the specified curing period.

Sprayed curing compounds shall only be permitted with the Contractors Method Statement and QA procedure is approved by the Engineer.

d. Shutter Ties

Internal shutter ties shall remain embedded in the concrete and shall be of a type specifically intended by the supplier for use in concrete subjected to hydrostatic pressure.

The ties shall be so constructed that no part of the permanently embedded portion is closer than 50mm to the concrete faces.

Any holes or depression resulting from the use of shutter ties shall be completely filled with 1:4 cement/sand mortar thoroughly compacted into the hole or depression.

e. Use of Joint Fillers

The joint filler shall be fixed to the face of the concrete already cast with a waterproof adhesive.

Where polysulphide sealants are to be used to seal joints containing a filler the Contractor shall ensure that the joint filler in use is a suitable backing material for the sealant and will not invalidate the supplier's warranties.

f. Polysulphide Sealants

Polysulphide sealants shall be mixed and used strictly in accordance with the manufacturer's instructions. The sealant shall in no circumstances be less than 12mm thick and for joints exceeding 25mm wide the minimum thickness shall be not less than half the width of the joint.

The faces of the concrete in contact with the sealant shall be primed according to the supplier's recommendations. The concrete shall be clean and dry when the primer is applied. If necessary the concrete shall be dried locally using a hot air gun or gas torch taking care not to overheat the concrete (The contractor shall note that the aggregates in concrete are likely to explode if allowed to get too hot and protective clothing and goggles must be worn).

18.4 Preliminary Inspection

- a. After completion of the tank and before any finishes are applied the contractor shall prepare the structure for inspection by the Engineer so that a check can be made on the exclusion of any external ground water which may be present. For the purpose of this inspection any collected water must be removed and all surfaces dried off. If the roof has not been constructed the contractor shall allow for protecting the tanks from rainfall.
- b. Any work which shows visible signs of water penetration or damp staining will be rejected. The contractor shall obtain the consent of the Engineer for the remedial methods, which he proposes to use before making good any work so rejected.
- c. When the tank are shown to be excluding external water as described in the preceding paragraph the tanks shall be tested for water tightness when filled with water.

19. Testing and Water Tightness Acceptance

19.1 General

- a) In the case of structures which are sub-divided into individual tanks (such as the reservoirs), each individual tank shall be tested separately. In the case of underground or semi-underground structures, the testing is to take place before any perimeter drain or filter material or backfilling is placed against the walls. No placing of any material whatsoever against the walls shall take place until the Engineer has given his written approval and acceptance of the tank as watertight.
- b) The testing shall not be undertaken until the structure to be tested has been completed structurally (including roof if any) and has been passed by the Engineer in writing as satisfactory in all respects other than water-tightness, especially in regard to the final finish of the work, the filling shall not take place earlier than 28 days after the casting of the final sections of the structure which will be stressed by the filling of the structure.

- c) Before and during testing, flows in the reservoir underdrainage shall be monitored, measured and recorded. Each underdrain shall be numbered and observations reported by underdrain number to facilitate analysis of the data. All leaks shall be repaired within one month of their detection.
- d) Two sets of evaporation trays shall be provided along with two sets of rain gauges. Levels in the trays and reservoir shall be made and recorded by a hook gauge with vernier attachments.
- e) The structure shall be filled with potable water in stages not exceeding one meter in height and held at each water level for such time as the Engineer may require. Should any dampness or leakage occur at any stage, the remedial works shall not start until reaching to the final filling level.

19.2 Testing of Structures

- a) After completion and cleaning of the reservoir and all associated pipework, the Contractor shall fill the reservoir with water up to top water level and leave for 7 days. Water shall be added over this period to maintain the top water level.

The Contractor shall ensure that all pipes and specials are available in ample time ahead of testing.

- b) On the eighth day two shallow watertight evaporation trays of area 0.4 sq meters shall be filled with 75 mm depth of water and placed to float in the tank. The water levels shall be recorded and the test commenced and carried out over the next 7 days. Readings of the water levels in the reservoir and trays shall be made and recorded every 24 hours over this period.
- c) The fall of water level in the tank over the test period of 7 days, after allowing for evaporation and rainfall shall not exceed 1/500 of the average water depth of the full reservoir or 10mm whichever is less.
- d) Notwithstanding the satisfactory completion of the 7 day test, any leakage, cracks, wet/damp patches and sweating visible on the outside faces of the structure shall be rectified from the water face as directed by the Engineer, a repair making the outface only watertight will not be accepted, this applies to

bobbin holes also. The structure shall be re-tested until the water-tightness is approved by the Engineer.

- e) The roofs of reservoirs and tanks shall be tested for water tightness by covering the roof slabs to a minimum depth of 50 mm for a period of 72 hours. The roof slab shall be considered satisfactory if no leaks or damp patches appear on the soffit.
- f) Should the part of the structure under the test fail the above tests in any respect, the Contractor shall immediately take such steps as may be necessary to ascertain the nature and positions of any defects or leakages, shall empty the structure, and remedy the defects in a manner approved by the Engineer, employing men or a firm who are specialists in this class of work.
- g) When the remedial work has been completed in a manner approved by the Engineer, the testing and if necessary rectifications, shall be repeated until a satisfactory test is achieved.
- h) If necessary, in extreme cases of lack of water tightness, the Engineer may reject the structure or any member or section of a member of the structure.
- i) All expenses in materials (including the supply of water) plant, labour and all other costs including overheads and profit if required involved in the satisfactory water-tightness testing of all the water-retaining structures in the Works shall be included in the rates entered by the Contractor in the relevant items in the Bill of Quantities.
- j) Any costs, as above, incurred by the Contractor in remedial or replacement work necessary to achieve the satisfactory testing shall be entirely at the expense of the Contractor.

19.3 Time of Testing

The Contractor shall obtain the agreement of the Engineer to the time during the Contract Period at which the testing takes place. In no circumstances will testing be permitted before 28 days have elapsed from the time of placing the final concrete in the tank construction.

19.4 Water for Testing

The Contractor shall be responsible for obtaining and disposing of the water used during the tests. He shall obtain the consent of the Engineer and of the appropriate Ministry prior to the test period.

water used for testing shall be potable water. The cost of obtaining this water shall be borne by the Contractor at his expense.

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