CHAPTER 3

CONCRETE WORKS

3.1 Cast in place Concrete

3.1.1 Scope of Work

The Contractor shall provide all labour, equipment, materials and incidentals required to furnish mix, transport, and place all concrete and install miscellaneous related items including forms, sleeves, anchor bolts, inserts and embedded items.

3.1.2 Definitions

A. Water/Cement Ratio: the ratio by weight of water to cement in a mix, expressed as a decimal fraction. Water being that which is free to combine with cement, including free water in aggregate but excluding that absorbed by the aggregate.

B. Construction Joint: a joint in the concrete introduced for convenience in construction at which special measures are taken to achieve subsequent continuity without provision for further relative movement. The surface where two successive placements of concrete meet, across which it is desirable to develop and maintain bond between the two concrete placements and through which any reinforcement which may be present is not interrupted.

C. Movement Joints: a joint intended to accommodate movement between adjoining parts of a structure, special provision being made where necessary for maintaining the water tightness of the joint. Typical movement joints provided are: expansion joints; complete contraction joints; partial contraction joints; sliding joints and hinged joints.

D. Expansion Joint: a separation between adjoining parts of a concrete structure which is provided to allow small relative movements such as those caused by thermal changes to occur independently.

E. Contraction Joint: formed, sawed, or tooled groove in a concrete structure to create a weakened plane and/or to regulate the location of cracking resulting from the dimensional change of different parts of the structure.

F. Fair Face Concrete: a concrete surface which, on completion of the forming process, requires no further (concrete) treatment other than curing (See also architectural concrete).

G. Architectural Concrete: concrete which will be permanently exposed to view and which therefore requires special care in selection of the concrete materials, forming, placing, and finishing to obtain the desired architectural appearance.

H. Water retaining structure: any structure or any part of which will contain water or process liquids, or aqueous liquid.

3.1.3 General Provisions

Concrete shall be composed of portland cement, fine aggregate, coarse aggregate, water and admixtures, as specified, and shall be made at the site of the work, except as otherwise authorised in writing by the Engineer. Central mix or transit mix concrete may be permitted, provided it can be placed within the time requirements specified, and complies with all of the provisions herein specified.

Reinforced concrete and workmanship shall conform to ACI 318, "Building Code Requirements for Reinforced Concrete" or BS 8007: 1987 "British Standard Code of Practice for Design of Concrete Structures for Retaining Aqueous Liqiuds" or BS EN 1992-3:2006 "Eurocode 2 – Design of Concrete Structures – Part 3 : Liquid retaining and containment structures" as directed by the Engineer. For Reinforced Concrete Structures other than Retaining Aqueous Liqiuds, shall conform to BS 8110:1997 British Standard Code of Practice for Design of Concrete Structures or BSEN 1992-1-1:2004+ A1:2014 "Eurodode 2 – Design of Concrete Structures – Part 1-1:General rules and rules for buildings" as directed by the Engineer.

All testing and inspection services required, will be done at no additional cost to the Employer at the field laboratory provided by the Contractor as specified in the Chapter 1, or as instructed by the Engineer. Methods of testing will comply in detail with the applicable ASTM "Methods of Test."

3.1.4 Submittals

A. Product Data

1. Cement:

    a. Manufacture of cement shall be subject to the Engineer's approval prior to the delivery and at the time of delivery.

    b. Manufacturer's test sheets shall be supplied with each consignment of cement certifying compliance with the relevant standard.

    c. The Contractor shall submit the date of manufacture and prove that the specifications have been complied with, certified by an accredited agency in the country of Manufacturing acceptable to the Engineer.

    d. In case of imported cement at the time of delivery means the time of delivery to the site.

2. Reinforcement

    a. The Contractor shall furnish the manufacturer's records of chemical and physical properties of steel bars and a certificate of the steel reinforcement specified. The manufacturer's records shall include mill certificates as well as chemical analysis, tensile and bend tests.

    b. The steel test report shall be furnished for each consignment of steel reinforcement to prove compliance with the relevant Sri Lankan Standard or any other equivalent Standard approved by the Engineer.

3. Aggregate

   The Contractor shall submit details of proposed aggregate sources for approval by the Engineer.

4. Water

   The Contractor shall submit details of proposed water source for approval by the Engineer. The details shall include the chemical analysis and a certificate from an independent testing agency that the specifications have been complied with.

5. Admixtures

   The Contractor shall submit the manufacturer's technical recommendations and specifications for any additives proposed.

6. Current test reports and written certificates for waterstops, joint filler board, joint sealant and primer, slip membrane, sealing strip membrane and repair materials shall be submitted to the Engineer for review and approval.

B. During the mobilisation period the Contractor shall submit for the approval of the Engineer a method statement detailing his proposals for the organisation of concreting activities for each structure or type of structure. The method statements shall be approved before any concrete is placed. Any alteration in the source of quality or proportioning of any of the materials in the mix will necessitate a new method statement. Method statements shall be prepared for each grade and type of concrete in the Contract and shall include, but not limited to, the following details:

1. Plant proposed,
2. Layout of concrete production facility,
3. Proposed method for production of concrete,
4. Quality control procedures for concrete and concrete materials,
5. Transport and placing of concrete including the use of chutes, conveyor belts or pumps as a means of transporting concrete.

C. Shop Drawings

   a. The Contractor shall submit shop drawings showing the proposed layout of all construction joints; details for the installation of waterstops in movement joints including location of joints, intersections and changes of direction with cross sections; consolidated shop drawings showing all mechanical penetrations.

   b. Detail fabrication and placement drawings for all reinforcing steel.

   c. Drawings shall consist of sections, plans and details clearly showing locations, sizes, spacing and shapes of all reinforcing steel, caps and spaces supporting bars and accessories.

d. Include bar bending schedules and diagrams to indicate bends, sizes and lengths of all reinforcement prepared in accordance with BS EN ISO 3766: 2003.

e. A separate set of shop drawings, showing construction joint locations, shall also be submitted for approval and shall indicate all floor openings, wall openings and edges of concrete. Floor openings, wall openings, pipe inserts and sleeves for all mechanical, plumbing and electrical work shall be co-ordinated with the respective trades and shown on these shop drawings in accordance with the criteria indicated on the Contract Drawings.

D. Samples

1. Reinforcement

(i) Representative samples of all reinforcing steel that the Contractor proposes to use in the Works must be submitted to the Engineer for his written approval, before work is commenced. The Contractor shall submit manufacturer's certificates stating clearly for each sample's:

a. Place of manufacture,
b. Expected date and size of deliveries to site,
c. All relevant details of composition, manufacture, strengths and other qualities of the steel.
d. Conformity to relevant Standards.

(ii) The Engineer reserves the right to sample and inspect all reinforcement steel upon its arrival at the work site.

(iii) The Contractor shall provide a certificate confirming that samples taken from the bars delivered to the works pass the re-bend test.

(iv) Frequency of sampling and the method of quality control shall be in accordance with Appendix C of BS 4449 or relevant equivalent Standards.

2. Slide bearings: The Contractor shall provide at least three samples of material proposed, including the manufacturer's technical specifications, application recommendations, and anticipated performance.

3. Slip joints: The Contractor shall provide at least three samples of materials proposed including manufacturer's technical specifications, application recommendations, and anticipated performance.

4. Waterstops & membranes: The Contractor shall provide at least three samples of proposed types, including prefabricated joints and junctions, if applicable. If joints are to be made up on site, provide worked samples including samples for each make of waterstop and membrane, where different manufacturers are used.

5. Cement samples shall be provided from each consignment delivered to the Site as required by the Engineer for testing.

6. Aggregate: The Contractor shall provide samples of both fine and coarse aggregates to the Engineer for testing. Samples shall be taken in the presence of the Engineer or Engineer's representative. Aggregate samples shall be provided at least one month prior to beginning deliveries to site. The test report shall be provided for the approval of the Engineer.

E. Mix Design

For each grade and type of concrete in the contract and shall include:

1. The method of design of the mix, by reference to a recognised published design method.
2. Designed aggregated proportions shall be based on measured and not assumed relative densities.
3. Proposed mix proportions including any proposed admixture.
4. Results of testing of trial mixes to demonstrate that the proposed mix complies with the strength and workability requirements of this specification.
5. For mix designs which include an admixture, trial mixes shall be prepared and tested both with and without the admixture to give a clear indication of its effects on the physical characteristics of the mix.
6. The mix design shall include w/c ratio, type of cement and dosage and type of admixture and dosage.

F. Schedules and programme

The scheduling and programming requirements specified in other sections, the Contractor shall submit to the Engineer for his approval as soon as practicable, and not less than three days before commencement of concreting on a structure, a program detailing concrete placement sequences. The programme shall include details of: estimated time for pours; size of each pour; time of commencement and finish and staff, machinery and plant assign for placing of concrete.

G. Quality Assurance Records

1. Slump
2. Cube strength at 7 days and 28 days
3. Cylinder strength at 7 days and 28 days

Samples of constituents and of concrete as placed will be subjected to laboratory tests. The Contractor will submit samples as directed by the Engineer. All materials incorporated in the work shall conform to the approved samples.

The Contractor shall design the concrete mixes for all classes of concrete and submit his proposal together with the test results of the strength of all classes of the concrete mix design for the approval of the Engineer. The design of the concrete mixes and the concrete strength test shall be made in the field laboratory in the presence of the Engineer's representative. The Contractor is responsible for all expenses incurred in this process.

Prior to any major concreting as instructed by the Engineer, the Contractor shall submit a method statement furnishing all the relevant details including the plants he intends to use, for the approval of the Engineer.

H. Non Destructive Test

It shall be necessary to test concrete structures after the concrete has hardened to determine whether the structure is suitable for its designed use. This testing shall be done without damaging the concrete. The tests shall be available for testing concrete range from the completely non-destructive, where there is no damage to the concrete, through those where the concrete surface is slightly damaged, to partially destructive tests, such as core tests and pullout and pull off tests, where the surface has to be repaired after the test.

Non-destructive testing can be applied to both old and new structures. For new structures, the applications shall be for quality control or the resolution of doubts about the quality of materials or construction. The testing of existing structures shall be done to an assessment of structural integrity or adequacy.

Situations where Non Destructive Test shall be done for investigation of in-situ concrete:

- to investigate the homogeneity of concrete mixing
- lack of grout in post tensioning ducts
- to determine the density and strength of concrete in a structure
- to determine the location of reinforcing bars and the cover over the bars
- to determine the number and size/diameter of reinforcing bars
- to determine the extent of defects such as corrosion
- to determine the location of in-built wiring, piping, ducting, etc.
- to determine whether internal defects such as voids, cracks, delaminations, honeycombing, lack of bonding with reinforcing bars, etc. exist in concrete
- to determine if there is a bond between epoxy bonded steel plates and concrete member

The following methods shall be used for the Non Destructive Test of concrete:

- Visual inspection, which is an essential precursor to any intended non-destructive test. An experienced civil or structural engineer may be able to establish the possible cause(s) of damage to a concrete structure and hence identify which of the various NDT methods available could be most useful for any further investigation of the problem.
- Half-cell electrical potential method, used to detect the corrosion potential of reinforcing bars in concrete.

- Schmidt/rebound hammer test, used to evaluate the surface hardness of concrete.
- Carbonation depth measurement test, used to determine whether moisture has reached the depth of the reinforcing bars and hence corrosion may be occurring.
- Permeability test, used to measure the flow of water through the concrete.
- Penetration resistance or Windsor probe test, used to measure the surface hardness and hence the strength of the surface and near surface layers of the concrete.
- Covermeter testing, used to measure the distance of steel reinforcing bars beneath the surface of the concrete and also possibly to measure the diameter of the reinforcing bars.
- Radiographic testing, used to detect voids in the concrete and the position of stressing ducts.
- Ultrasonic pulse velocity testing, mainly used to measure the sound velocity of the concrete and hence the compressive strength of the concrete.
- Sonic methods using an instrumented hammer providing both sonic echo and transmission methods.
- Tomographic modelling, which uses the data from ultrasonic transmission tests in two or more directions to detect voids in concrete.
- Impact echo testing, used to detect voids, delamination and other anomalies in concrete.
- Ground penetrating radar or impulse radar testing, used to detect the position of reinforcing bars or stressing ducts.
- Infrared thermography, used to detect voids, delamination and other anomalies in concrete and also detect water entry points in buildings.

I. Slip Form Method

The slipform system is a hydraulically operated formwork system. This method shall be used to construct a concrete pavement slab without framing using special machinery. In the slip form method, paving shall done using a special-purpose slip form paver, without installing framing. With this method, concrete structures with the same cross-section are finished continuously using a steel mold. This system shall be used for ordinary concrete slabs and continuous reinforced concrete slabs.

Concrete shall be poured into the forms in layouts of approximately 200mm. The setting rates of concrete shall be constantly monitored to ensure that it is matched with the speed at which the forms are raised. The jacks shall be lifted the forms

approximately 25mm per stroke, generally producing a slipforming rate of.300mm to 450mm per hour.

Slipforming shall be performed on either a continuous basis (i.e. 24 hours per day), or a discontinuous basis (i.e. pouring to a predetermined height usually within one working day). As the formwork is raised, reinforcement shall be held in the correct position using guides fixed to the top of the yokes. Horizontal reinforcement shall be threaded under the yokes and tied to the vertical reinforcement.

Blockouts for doors and windows shall be formed with either timber or steel. These are installed as the slipform proceeds and shall be stripped from the trailing decks. Similar methods shall be used for rebates that provide connections between beams, slabs and the slipform walls.

When the formed concrete is exposed from the bottom of the steel forms it shall be treated to meet the specified finish.

The Contractor shall ensure the smooth operation of the slipforming process and control of verticality.

3.1.5 Materials

Samples of all materials shall be submitted to the Engineer for approval and tests required for approval as instructed by the Engineer.

(1) Cement

All cements shall comply with following standards;

Type	In accordance with
Ordinary Portland Cement	SLS 107 / BS EN 197-1:2011
Rapid Hardening Portland Cement	
White Portland Cement	BS EN197-1:2011
Coloured Portland Cement	
Portland Blast Furnace Cement	BS EN197-1:2011
Low Heat Portland Cement	BS EN197-1:2011
Sulphate Resisting Portland Cement	BS 4027:1996
Low Heat Portland Blast Furnace Cement	BS EN 197-1
Super Sulphated Cement	BS EN 15743:2010+A1:2015
Ultra High Early Strength Portland Cement Water repellent Portland cement Hydro-phobic Portland Cement	The requirements for physical properties for ordinary Portland Cement given in SLS 107 or BS EN197-1:2011
Portland Limestone Cement	SLS 1253
Blended Hydraulic Cement	SLS 1247
Masonry Cement	SLS 515

Note: (i) When cement other than those complying with requirements of SLS 107, BS EN 197-1:2011 are used, account shall be taken of their properties and any particular conditions of use.

(ii) Where Portland Blast furnace cement complying with BS 146 is used, the slower rate of hardening shall be given due consideration and adequate curing shall be ensured.

(iii) Super sulphate cements shall not be mixed with any other type of cement.

(2) Aggregate

All aggregates shall comply with standards given in the Specifications for Building Works volume-1.

Aggregates shall be hard and not content materials such as coal, pyrites, lumps of clay etc. that are likely to decompose or change in volume when exposed to the weather, or affect the reinforcement (where provided). Aggregates with low absorption value shall be used for all concrete that is exposed to the weather or in contact with liquids.

The Aggregates shall be free from soft, friable, thin elongated or laminated pieces, coating of dust, and from clay, alkali, organic or any foreign matter. The contractor shall wash thoroughly all aggregate or any portion of it delivered to the works if so directed by the officer-in-charge.

General

1 Shall consist of tough, hard durable and uncoated particles containing no harmful material in quantities sufficient to adversely affect the concrete or reinforcing steel.

2 Shall comply with the requirements of BS EN 12620: 2002 except as modified hereunder and shall be washed clean with potable water, if necessary to comply with these requirements.

3 Contractor shall provide all data as specified in Appendix A of BS EN 12620: 2002.

4 Contractor shall satisfy the Engineer that the aggregates to be supplied will not give rise to an alkali reaction with the cement.

5 Should have a low coefficient of thermal expansion.

6 Sampling and testing of aggregates shall be carried out in accordance with the requirements of the appropriate section of BS 932-1:1997.

7 Fine aggregate shall be natural sand or crushed metal (M- sand).

8 Beach sand shall not be permitted for use in concrete mixes.

9 Aggregates shall meet the requirements of Table A.

10 Frequency of routine testing of aggregates shall be in accordance with Table B.

11 Mineralogical tests are to be carried out as and when directed by the Engineer.

12 No aggregate deliveries shall be made to the site until the Engineer has approved the samples as complying with these specifications.

13 Samples of aggregates will be tested at intervals during construction of the works and the Contractor shall provide the necessary equipment and labour.

TABLE A: Requirements of Aggregate

	Requirement	**Test Methods**		**Permissible Limits**	
		As specified	**ASTM**	**FINES**	**COARSE**
1.	Grading	BS EN 932-1:1997		Standard	Standard
2.	Material finer than 0.075 mm Natural, uncrushed/ Crushed	BS EN 932-1:1997		Max. 3%	Max. 1%
	Crushed rock			Max. 5%	Max. 3%
3.	Clay lumps and friable particles		C142	Max. 3%	Max. 2%
4.	Light weight pieces		C123	Max. 0.5%	Max.0.5%
5.	Organic impurities		C40	Colour standard not darker than Plate No. 3	
6.	Water absorption		C128/C 127	Max. 2%	Max. 2%
7.	Specific Gravity (apparent)		C128/C 127	Min. 2.6	Min. 2.6
8.	Shell content: Coarser than 10 mm Between 5 mm & 10 mm	BS EN 933-7:1998			 Max. 3% Max. 3%
	Between 2.36 mm & 5 mm Finer than 2.36 mm			Max. 10% Note 1	
9.	Particle shape: Flakiness index	BS EN 933-3:2012			Max. 25%
	Elongation index				Max. 25%
10.	Acid Soluble Chlorides: A. For reinforced concrete	BS EN 1744-1:2009+			

	with: SRPC OPC & MSRPC	A1:2012		 Max.0.06% Max.0.06%	 Max.0.03 % Max.0.03 %
	B. For mass concrete made with: SRPC OPC & MSRPC			 Max.0.06% Max.0.06%	 Max.0.03 % Max.0.03 %
	C. For prestressed & Steam cured structural concrete			Max.0.01%	Max.0.01 %
11.	Acid Soluble Sulphates	BS EN 1744-1:2009+ A1:2012		Max. 0.3%	Max. 0.3%
12.	Soundness,($MgSO_4$ -5 Cycles)		C88	Max. 10%	Max. 10%
13.	Mechanical Strength:10% fines value	BS EN 1097-2:2010			Min 150 kN
	Impact value	BS EN 1097-2:2010			Max. 30%
	Loss Angeles Abrasion		C131/C 535		Max. 20%
14.	Drying Shrinkage	BS EN 1367-4:2008			Max. 0.05%
15.	Potential reactivity: Note 2 Of Aggregates, Chemical Method			Not Reactive	Not Reactive
	Of Cement-Aggregate Combination			6 month expansion 0.10% max.	

Note 1: There is no requirement of shell content in sands passing 2.36 mm sieve size.

Note 2: Aggregates may initially be assessed for its reactivity in accordance with ASTM C289 and if potential reactivity is indicated, then mortar bar tests in accordance with ASTM C227 shall be carried out.

TABLE B: Frequency of Routine Test Requirements

	Requirement	**Test Method**	**Test Frequency**
1.	Grading	BS EN 933-1:2012	Each 2 weeks or per 100 m^3 which ever is more frequent
2.	Material finer than 0.075 mm	BS EN 933-1:2012	-do-
3.	Clay lumps and Friable Particles	ASTM C 142	-do-
4.	Organic Impurities	ASTM C 40	Each month or per 200 m^3 whichever is more frequent
5.	Water Absorption	ASTM C128/C127	-do-

6.	Specific Gravity	ASTM C128/C127	-do-
7.	Shell Content	BS 812 : Part 106	Each 2 months or per 100 m^3 whichever is more frequent
8.	Particle Shape	BS EN 933-3:2012	-do-
9.	Acid Soluble Chlorides, Cl Quantitative	BS EN 1744-1:2009 + A1:2012	On each delivery to site
	Quantitative	BS EN 1744-1:2009 + A1:2012	Each week, if result is more than 75% of the limit and each month if result is less than 75% of the limit.
10.	Acid Soluble Sulphates, S03	BS EN 1744-1:2009 + A1:2012	Each two weeks if result is more than 75% of the limit & each two months if result is less than 75% of the limit.
11.	Soundness (Mg S04 - 5 cycles)	ASTM C88	Each month.
12.	Mechanical Strength		
	10% Fines or Impact Value	BS EN 1097-2:2010	Each month
	Los Angeles Abrasion	ASTM C 131/C 535	-do-
13.	Moisture variation in sand - by Moisture Meters		Twice daily
14.	Drying Shrinkage	BS 812 : Part 120	At the start of the project and whenever there is a change in the source of supply.
15.	Potential Reactivity: Of aggregates Of carbonate Of cement aggregate combination	 ASTM C295/C289 ASTM C586	 At the start of the project and wherever there is a change in the source of supply.

- Dense Aggregate

  These shall consist of one of the following:

  Coarse and fine Aggregate from Natural Sources shall comply with the requirements of EN 12260:2002.

- Coarse Aggregate

  The coarse Aggregate shall be crushed stone that is mainly retained on a 5mm test sieve comply with BS ISO 3310-1:2016 or equivalent, and containing only so much finer material as is permitted. The stone shall be from an approved quarry and shall be clean, sharp, undecomposed gneiss or other approved metamorphic or igneous rock having clean, hard dense and durable fragments.

- Fine Aggregate

Fine Aggregate passing a 5 mm BS ISO 3310-1:2016 (or equivalent) and containing material as is permitted shall be:

a) Natural sand – obtained from the natural disintegration of rock, i.e. it shall be clean, sharp, river or pit sand free of earth, silt, clay loam carbon, alkali, mica, organic matter and other deleterious substances.

b) Crushed stone sand – the use of this shall be permitted only for designed mixes. Crushed stone sand shall be manufactured from hard tough durable uncoated rock.

(3) Water

A. Water used for concrete-mixes, washing of equipment, wetting of surface or ponding during curing or for wetting formwork and washing reinforcement shall be potable water and shall comply with the requirements of SLS 522 except as modified hereunder. The Contractor shall make his own arrangements and obtain approval for the supply of water.

B. The pH of water used in concrete works shall be not less than 6.0 or more than 9.0.

C. Water for curing concrete shall not contain impurities in sufficient amounts to cause discolouration of the concrete. Source of water shall be maintained in such a manner as to exclude silt, mud, grass and other foreign matter.

D. Whenever required to do so by the Engineer the Contractor shall take samples of the water being used or which it is proposed to use for mixing concrete and test them for quality. Samples of water not less than 5 litres shall be taken, sealed and sent for testing at an approved independent laboratory prior to the approval of any water source and periodically during the continuance of its use.

E. No source of water shall be used until the required tests have demonstrated its suitability for concreting.

(4) Admixtures

A water reducing agent conforming to ASTM C494 or BS EN 934 shall be used in all concrete. The Contractor may also be required to use a retarding, or water reducing and retarding admixture conforming to ASTM C494 or BS EN 934 and as approved by the Engineer, under conditions contributing to early set of concrete, or when the temperature of concrete is 30^{0}C or above, or when the time between introduction of cement to the aggregate and placing of concrete exceeds 45 minutes. If admixtures are used, it will be at the Contractor's option and at no additional cost to the Employer.

Unless approved in writing by the Engineer, admixtures causing accelerated setting of cement in concrete shall not be used.

Compatibility of all proposed admixtures shall be tested for compatibility with

proposed cement and aggregate in accordance with ASTM C494 or BS EN 934.

The amounts and types of additives used shall be as directed or approved by the Engineer and may be varied by him according to the location of the work or for other reasons.

A. Admixtures shall mean materials added to the concrete materials during mixing for the purpose of altering the properties of the concrete mix.

B. Where approved and or directed by the Engineer, admixtures shall be used as a means of increasing concrete durability; increasing workability of the concrete without increasing the water/cement contents; or controlling and limiting retardation of setting.

C. Admixtures shall comply with the requirements given below:

Water Reducing Admixture	ASTM C 494 type A EN 480:2005 and EN 934:2009
Retarding Admixture	ASTM C 494 Type B EN 480:2005 and EN 934:2009
Water Reducing, high range and retarding admixtures	ASTM C494 Type G

D. The methods of use and the quantities of admixture used shall be subject to the Engineer's approval and shall in no way limit the Contractor's obligations under the contract to produce concrete with the specified strength, workability and durability.

E. In addition to the standard requirements for approval of materials, approval of admixtures shall be subject to extensive trials to demonstrate the suitability, adequacy of dosing arrangements and performance

F. The use of the admixtures shall be controlled i.e. strict quality control to ensure correct dosages as prescribed by the manufacturer are used. Admixture is to be dispensed by a transparent unit which enables the operator to see the discharge.

G. Concrete supplier shall furnish a series of at least 10 trial mixes which clearly indicate that the use of the admixture has consistently exhibited the specified absorption, permeability and pouring values. These are to be verified by an approved independent laboratory. The concrete supplier shall also conduct (with the above) a trial showing that a control mix without the admixture does not exhibit a greater density than that incorporating the admixture.

H. No admixtures containing chlorides shall be used.

I. The Contractor shall provide sufficiently large capacity in his concrete producing plant and concrete transporting arrangements and use an appropriate admixture to avoid cold joints. The Contractor shall be entirely responsible for the use of any approved admixture at no additional cost to the Employer and in

strict accordance with the Manufacturer's instructions.

J. The Contractor shall provide the following data and ensure that the product complies with the following specifications:

1. Admixtures which comply with ASTM C494 (or BS EN 934) Type G shall be employed to:

   a. Produce highly flowable and self compacting concrete at the lowest possible water cement ratio or as specified.

   b. Produce a consistency of concrete that is free of bleeding and segregation.

   c. Provide slump retention and set control as and when applicable.

   d. Offer the user impermeability and durability.

2. Admixture shall be based on naphthalene sulphonates. Where deemed necessary lignosulphonate admixtures conforming to ASTM C494 Type B may also be employed providing this is to the satisfaction of the Engineer.

K. Hydrophobic Pore Blocking Admixtures: If in the opinion of the Contractor a hydrophobic pore-blocking admixture is required to achieve the requirements specified herein, the Contractor may use an admixture based on ammonium stearates and hydrocarbon resin at no additional cost to the Employer. The admixture is to be added at a dosage recommended by the manufacturer at the time of mixing. The manufacturer's representative is to be present for all additions of the hydrophobic pore blocking compound to ensure correct dosage rates are used.

3.1.6 Delivery & Storage of material

3.1.6.1 Delivery & Storage of Cement

Cement when being conveyed to the Site in lorries or other vehicles, shall be adequately protected form the weather and from contamination by dust, sand or any organic materials. Any cement which shall prove to have been exposed to damage by water will be rejected upon delivery.

All cement shall be stored in a weatherproof, waterproof and reasonably airtight building provided solely to that purpose. The floors of the building shall be raised at least 300 mm above the ground level to prevent the absorption of moisture.

The cement shall be placed on a raised platform and amply protected by waterproof coverings to the approval of the Engineer. It is not permitted to store bags to a height greater than 2 metres. In the case of delivery of cement in bulk, the cement shall be stored in a properly designed silo. The silo shall be waterproof and must be provided with walls properly insulated against sunlight.

Where silos are used for the storage of cement each silo or compartment thereof shall

be completely separate and fitted with a filter or an approved alternative method of dust control. Each filter for dust control system shall be of sufficient size to allow delivery of cement to be maintained to prevent undue emission of dust and to prevent interference with weighing accuracy by build-up of pressure. The Engineer shall be furnished with the means of identifying the several consignments of cement delivered. Each consignment of cement shall be stored separately so as to provide easy access for inspection and testing.

After they have been approved by the Engineer, consignments shall be used in the order in which they were delivered. No cement shall be taken from the storage unless it is needed for immediate use.

The testing of cement shall be carried out in accordance with the provisions of relevant SLS standard or as directed by the Engineer. If cement has been stored on the site for more than 40 days or in the opinion of the Engineer is of doubtful quality, new tests may be required, at the Contractor's expense, to check whether the cement is still conforming to the requirements.

Notwithstanding the receipt of a test certificate the Engineer may reject any cement as a result of further tests. The Engineer may also reject cement which has deteriorated owing to inadequate protection or other causes, or in any other case where the cement is not to his satisfaction. The Contractor shall remove all rejected cement from the Site without delay and at the Contractor's expense.

3.1.6.2 Delivery & Storage of Aggregate

Delivery of Aggregate shall done with due consideration protect the environmental requirements. Lorries or trucks with aggregates shall always be covered with a hard cover and shall conform to the regulations of the Central Environmental Authority of Sri Lanka.

Aggregates shall be separately stored so as not to become mixed with one another and so as to prevent contamination. Materials of similar gradings but from different sources or different types, shall not be stored together unless approved.

Aggregate stockpiles shall be provided with impervious beds laid to facilitate drainage, and any adjacent roads shall be so formed as to prevent drainage to the stockpiles and bin loading areas.

Aggregate stockpiles shall be covered by a structure or structures which shall remain in position throughout the Contract and this cover shall effectively protect the stockpiles from rain. For each size of aggregate, separate duplicate stockpiles shall be provided and worked on alternate days to allow all aggregates to drain for at least 16 hours prior to use to obtain surface saturated conditions for concrete.

Aggregate in stockpiles shall not be contaminated or crushed by trucks, bulldozers, or other plant equipment.

The Contractor shall avoid the build-up of fine material at the bottom of the stockpiles. Should such build-up occur, the layer which contains an excess of fine material shall be removed to obtain well graded fine aggregate.

3.1.7 Water Stops

A. Materials shall be sourced and supplied by a single manufacturer. Technical service during installation is to be provided by the manufacturer at no additional cost to the Employer.

B. PVC or nitrile rubber water stops shall be extruded from a high grade elastromeric polyvinyl chloride compound which contains plasticizers, resin stabilizers and other materials necessary to meet the performance requirements of this specification. Rubber and PVC waterstops shall be suitable for storage, handling, installation and service within a range of 15°C to 50°C.

C PVC waterstops shall be manufactured from PVC conforming to BS 2571:1990, or approved equal and shall not contain recycled or filler material. The minimum tensile strength shall be 13.8 N/mm^2. Elongation at break shall be minimum 300 percent and Shore A hardness shall be 80-90. The waterstop shall be fully continuous and coordinated four bulbed section. Testing shall be carried out in accordance with BS 2782:2011.

D Rubber waterstops shall be to US Federal Specification 22R-601a, except that compression shall be to ASTM D395-18 and hardness shall be to ASTM D2240. Minimum tensile strength shall be 20.7 N/mm2 and elongation at break shall be minimum 450 percent.

E Waterstop intersection & transition pieces shall be pre-formed and/or prefabricated factory moulded type. Joints shall be heat sealed.

F External waterstops for base slab expansion joints shall be minimum 250 mm wide with four bulbs and ten parallel lines of fins. Centre box section shall be 25 mm wide and flat to accept a filler board. It shall have an outer nailing flange with a reinforced and profiled edge to resist tear when fixed to shuttering with double headed nails and shall be provided with an additional key when cast into the concrete.

G External waterstops for base slab construction and contraction joints shall be minimum 250 mm wide with four bulbs and ten parallel lines of fins and shall incorporate a central fin 22 mm high, as a shutter stop. They shall have an outer nailing flange with a reinforced and profiled edge to resist tear when fixed to shuttering with double headed nails and shall be provided with an additional key when cast into the concrete.

H Internal waterstops for wall and roof expansion joints shall have a centre box to accommodate movement and shall be minimum 250 mm wide with four bulbs and ten parallel lines of fins. The centre box section shall be flat to accept a filler board. The web shall be 10 mm thick with a thickened central section to transfer stresses to the centre bulbs. The waterstop shall have a reinforced eyelet outer flange for secure fixing of the waterstops into position.

I Internal waterstops for wall and roof construction and contraction joints shall be minimum 250 mm wide with four bulbs and ten parallel lines of fins. The web shall be 100 mm thick with a thickened central section to transfer stresses

to the centre bulbs. The waterstop shall have a reinforced eyelet outer flange for secure fixing of the waterstop into position.

J Water bars shall be arranged so that there is a minimum distance of 25 mm from the water bar to the reinforcement. Waterstops shall not be nailed or damaged in any way. The Contractor shall ensure that the concrete surrounding the waterstop is fully compacted without the waterstop being displaced. Water stops shall be Water Research Council (WRC) approved for use in contact with potable water.

3.1.8 Joint Sealant, Joint Fillers & Movement Joints

A. Joint fillers shall be non-absorbent, semi rigid, closed cell, heat laminated polyethylene filler board and shall be non-tainting in accordance with BS 6920-1:2014. They shall be fully compatible with the surface sealants and if elastometric sealants are used the joint filler shall act as a bond breaker. Performance properties of the joint filler shall be as follows:

Recovery	Greater than 98% after 50% compression
Extrusion	Nil (three edges restrained and sample compressed by 50%)
Density	100 kg/m^3 $\pm$ 5 kg/m^3
Water Absorption	less than 1%

B. Joint sealants shall be two part polysulphide complying with BS EN ISO 11600: 2003+A1:2011 and must, in all cases, be carefully selected as appropriate for their climatic and environmental exposure. Where appropriate, they shall be resistant to biodegradation. Movement capacity of the sealant must be at least 20 percent of the joint width. The Contractor must apply written recommendations and guarantees from the manufacturers as to the suitability of the product for each individual structure and the method of installation. Primers shall have no harmful effects on concrete. Where required, masking tape shall be applied to protect the concrete surface on either side of the joint during priming and sealing operations. Masking tape must be stripped carefully away after joint sealing to leave near edges to the seal.

C Primer shall be as recommended by the sealant manufacturer.

D Bond breaker shall be forced, non-absorbent polyethylene backing strip or equals as recommended by sealant manufacturer to prevent adherence of sealant to backup material.

3.1.9 Slip Membrane

Slip membrane shall be preformed low friction bearing strip to form a thin sliding joint with a minimum bearing capacity of 0.7 N/mm^2. It shall be extruded from specially formulated polyethylene to form a durable lamina, resistant to most chemicals, solvents and weathering. It shall be applied in two layers with bottom layer bonded to substrate with high quality solvent borne adhesive based on polychloroprene rubber. The thickness shall be 1.5 mm minimum. Coefficient of static friction shall be 0.15 and it

shall be suitable for operating temperatures up to 50°C.

Sealing strip membrane: Where indicated on the Drawings, expansion joints shall be sealed with a sealing strip system. The joints shall be pre-sealed using sealant prior to laying sealing strip membrane. The sealing strip system shall comprise of hypalon high-polymer flexible sheeting bonded to the concrete surfaces on either side of the joint using suitable epoxy resin adhesive. The system proposed shall have high performance and shall allow considerable movements in more than one direction while maintaining a high quality seal. The width of the flexible membrane shall be 250 mm and the minimum thickness shall be 3 mm. The minimum unbonded width of the membrane shall be 50 mm, centred on the joint, to allow greater movement potentials. Masking tape shall be applied to achieve the required debonded width. The final sealing strip system shall be able to accommodate movement which results in the debonded area being extended up to 100 percent of the debonded width. The performance properties shall be:

Density	~1.65 kg/litre (adhesive)
	~1.50 kg/m^2 (hypalon /mm)
Service Temperature	~30°C to +70°C
Application Temperatures	Type Normal min. 10°C
	Type Rapid 5°C to 15°C
Bond Strength to Concrete	Dry or Damp =~ 4N/mm^2 (concrete failure)
Bond Strength to Steel	~6 N/mm^2 (strip failure)
Tensile Strength	~6 N/mm^2
Peel Strength	~4,5 N/mm^2
Elongation	>400 %

3.1.10 Vapour barrier

Vapour barrier/separation layer shall comprise two layers to underside of blinding concrete and ground slabs of gauge 1000 clear polyethylene sheets conforming to ASTM C 171. The physical properties for materials shall conform to ASTM E154.

3.1.11 Non-shrink grout

Non-shrink grout shall be non-metallic, chloride free, and epoxy grout formulated to comply with U.S. Corps of Engineers Specification CRD-C-621-81. When tested under conditions of ASTM-C827 it shall indicate non-decrease in volume change.

To aid strength and bonding of multiple layer application of grout the Engineer may order the use of non-shrink additive as follows:

Proportions

Material	Volume	Weight
Cement	1.0	1.0
Coarse Aggregate	0.1	0.25
Fine Aggregate	1.5	1.5

Additives	As recommended by the manufacturer

Non-shrink grout shall comprise of prepared, size graded aggregate combined with a catalysing agent and water reducing agent. When used in the proportioning of grout, mortar and concrete mixes, shrinkage shall be counter-acted and basic qualities improved. The Contractor shall demonstrate to the Engineer that the product has successfully been utilised on similar projects for a minimum of five (5) years. Preparation of surfaces, mix proportions, application procedures, and precautions shall be followed in strict compliance with the manufacturer's directions.

For very heavy (generally formed) applications, the Engineer may order the addition of pea gravel, passing a 3/8" screen but retained on a 1/4" screen, to the mixture with the proportions modified as follows:

Proportions

Material	Volume	Weight
Cement	1.0	1.0
Coarse Aggregate	0.2	0.33
Fine Aggregate	1.0	1.0
Pea Gravel	1.5	1.5
Additives	As recommended by the manufacturer	

In case where coarse aggregate is employed in multiple layers on exposed faces, the final 1.2 cm shall be composed of the 1:1.5 grout without coarse aggregate.

3.1.12 Dry Pack Mortar

Dry packing for areas over 75 mm wide shall have mix proportions of 1:1:2 (cement/fine aggregate/coarse aggregate 10 mm nominal size) by weight and the slump shall not exceed 5 mm. Dry packing for areas less than 75 mm wide shall have mix proportions of 1:2 (cement/fine aggregate) by weight and the slump shall not exceed 5 mm.

Dry pack mortar for filling holes and repairing surface blemishes shall be made from one part by weight of cement and three parts fine aggregate passing a 1 mm. sieve and an expanding agent approved by the Engineer. Additives to improve workability may be added to the approval of the Engineer. The colour of the mortar shall match that of the surrounding concrete. The mortar shall be mixed with only sufficient water to make the materials stick together when being moulded in the hands.

The dry pack material shall be placed and packed in layers having a thickness not greater than 15 mm. The compaction shall be carried out by use of hardwood stick and hammer and shall extend over the full area of the layer, particular care being taken to compact the dry pack against the sides of the hole. After compaction the surface of each layer shall be scratched before further loose material is added. Holes shall not be over filled and the surface shall be finished by laying a hardwood block against the dry pack fill and striking the block several times. Steel finishing tools shall not be used and water shall not be added to facilitate finishing.

3.1.13 Blinding Concrete

A blinding layer of minimum 75 mm. concrete grade 15/20 shall be placed under all foundations and ground slabs ordered by the Engineer. The blinding layer shall be allowed to harden before the structural concrete for the foundation is placed. A layer of polythene of thickness not less than 0.2 mm and of approved colour shall be placed prior to laying structural concrete. The polythene sheets shall be lapped not less than 300 mm.

3.1.14 Trial Mixes

A 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.

B Trial mixes shall be mixed for the same time and handled by means of the same which the Contractor proposes to use in the Works. Each mix shall be not less than 0.5 cu m of concrete.

C 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). Sieve analyses shall be made, by the method described in BS EN 932, of the fine aggregate and of each nominal size of coarse aggregate used.

D The slump of each batch of each trial mix shall be measured immediately after mixing by the method described in BS 1881 and shall be within the limits as specified.

E 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. Temperature, workability and density of concrete in each batch shall be determined. Three cubes shall be tested at seven days and three at 28 days, after manufacture in accordance with the method described in BS EN 12390-3:2019. If the average value of the strength of the nine cubes tested at 28 days is less than the trial mix strength given in Table 3.3, and/or the difference between the greatest and the least strengths is more than 20 percent of the average strengths, the Contractor shall remove from site, materials from which the trial mix was prepared and shall provide new materials and prepare and test further trial mixes until specified requirements are achieved.

F 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. Trial mixes 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 in accordance with the procedures described in later clauses. 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 re-designed by the Contractor. A further full-scale workability test shall be undertaken for that trial-mix of concrete.

G Re-design 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 meet the specified requirements and have the workability required to place it in the Works as demonstrated in the full scale workability test described above.

H The Contractor shall only use 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 paragraph 3.01 here-in, 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. If the values obtained are unacceptable, the mixes shall be re-designed:

1 Bleeding in accordance with ASTM C232 (non-vibrating) shall not exceed 0.5% or equivalent to BS or EN standard.

2 Shrinkage in accordance with BS ISO 1920-8:2009.

3 Air content of fresh concrete to BS EN 12350-7:2019.

4 Free water/cement ratio.

5 Workability (slump) to BS EN 12350-2:2019.

6 Fresh and hardened concrete densities to BS EN 12350-6:2009 and BS EN 12390-7:2019 respectively.

7 Compressive strength to BS EN 12390-32019.

8 Water permeability to DIN 1048 shall be maximum 10 mm at 28 days and maximum 15 mm at 7 days.

I 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 these Specification.

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

1 Mix for the works,
2 Type of plant used for mixing,
3 Method of compaction used,
4 Formwork face intended for use in the works.

K All costs connected with the preparations of trial mixes shall be borne by the Contractor.

L Whenever a change of brand or source for any of the concrete ingredients occurs, additional "preliminary tests" will be required and the cost of these tests shall be borne by the Contractor.

3.1.15 Concrete Reinforcement

A. **Reinforcing Steel:**

Reinforcing steel shall conform to SLS 26 or SLS 375 0r BS 4449: 2005 and shall have the following minimum yield strength. The yield strength of the reinforcing steel is defined as the stress corresponding to a strain of 0.35 percent, and shall correspond to that delivered by tests on full size bars.

Bars	Yield Strength	Symbol
Plain round mild steel	250 N/mm^2	R
Deformed high yield bars	460 N/mm^2	Y

All bars shall be sand blasted after fabrication. After fixing and immediately prior to placing of concrete the reinforcement shall be pressure-washed with fresh water.

Welded steel wire fabric shall conform to BS 4483:2005. Welded intersections shall not be spaced more than 310 mm for plain round bars or 400 mm apart for deformed high yield bars in direction of calculated stress except when used as stirrups.

Tie wire shall conform to SLS 139 or BS 4482:2005. No wires smaller than size D-4 shall be used.

Spacers shall be made of concrete, metal, or other as approved by the Engineer.

Welding, if permitted by the Engineer, shall conform to the requirements of AWS D 1.4 or BS EN 1011-2: 2001.

Reinforcing bars will be rejected if the weight of a bundle of one size of bars as delivered is underweight by 3.5 percent or more. An individual bar will be rejected if it is underweight by 6.0 percent or more.

B. **Testing of Reinforcement Steel**

Tests shall be carried out in strict accordance with SLS 375 or 26 or BS 4449:2005 and at the discretion of the Engineer from time to time.

Tensile tests providing information on the following will be required from each lot delivered:

1 Elastic limit,
2 Ultimate strength,
3 Stress-strain curve,
4 Cross-sectional area,
5 Deformation/bond characteristics of deformed bars

The Contractor shall allow for all tensile, bond, re-bond and chemical tests for each size of bar to be used in the concrete construction. Test results for each bar size shall be submitted to the Engineer. Further tests may be called for when the source of supply of reinforcement changes. When any test results do not conform to the relevant standard, the reinforcement steel shall be removed from the Site.

C. Delivery, Storage and Handling

(1) Delivery

a. Bars in each lot shall be legibly tagged by the manufacturer. The tag shall show the manufacturer's test number and lot number and other applicable data that will identify the material with the certificate issued for that lot of steel.

b. Fabricator shall furnish three copies of a certification which shows the heat number or numbers from which each size of bar in the shipment was fabricated.

(2) Storage

a. Reinforcement shall be stored on suitable structures a minimum of 450 mm above the ground surface and covered to prevent damage and accumulation of dirt, rust and other deleterious matter.

b. The storage facilities shall be such as to permit easy access for inspection and identification.

c. Bundles of reinforcement shall be clearly tagged with bar with the same. The identification tags shall be labelled with the same designations as shown on submitted bar schedules and shop drawings. These tags shall not be removed until the material is at the location where it is to be incorporated into the works.

d. Steel reinforcing bars shall be kept clean and shall be free from pitting, loose rust, mill scale, oil, grease, earth, paint, or any other material which may impair the bond between the concrete and the reinforcement.

e. Reinforcement shall not be handled roughly, dropped from a height, or subject to shock loading or mechanical damage.

(3) Manpower Material and Equipment

The Contractor shall provide all labour, materials, equipment and incidentals required to furnish and install all steel bars, steel wire, and steel supports required for the reinforcement of concrete as shown on the drawings and specified herein.

D. Shop Drawings

Detailed working and shop drawings and bar bending schedules of all reinforcement required for execution of the work shall be submitted for approval in accordance with the Conditions of Contract.

Include bar bending schedules and diagrams to indicate bends, sizes and lengths of all reinforcement prepared in accordance with BS EN ISO 3766: 2003.

The approval of shop drawings, or revised bar schedules shall in no way relieve the Contractor of his responsibility for the correctness of such drawings or schedules.

E. Cutting & Bending

Reinforcement shall be accurately fabricated to the dimensions indicated on the drawings. Particular care shall be exercised not to have stirrups oversized in order to maintain proper coverage of concrete. Stirrups and tie bars shall be bent around a revolving collar having a diameter not less than two and one-half times the minimum diameter of the bar or minimum specified in BS 8666:2005. Bends for other bars shall be made around a pin having a diameter not less than 6 times the minimum diameter except for bars larger than 25 mm diameter, in which case the bends shall be made around a pin of 8-bar diameter. All bars shall be bent cold. Bars reduced in section or with kinks or bends not shown on the drawings will not be accepted.

F. Installation

No reinforcing bars shall be welded either during fabrication or erection without prior written approval from the Engineer. If the Engineer approves the welding of reinforcing bars, the Contractor shall submit a sample of a welded piece together with test results of its strength which shall be not less than such reinforcing bar. Any bars that have been welded, including tack welds, without such approval shall be immediately removed from the work when instructed by the Engineer.

Before being placed in position, reinforcement shall be thoroughly cleaned of loose mill scale, dirt, and other coatings that reduce or destroy bond. Where there is delay in depositing concrete after reinforcement is in place, bars shall be reinspected and cleaned where necessary.

Reinforcement shall be accurately positioned as indicated on the drawings, and secured against displacement by using iron wire ties of not less than No.18 gauge, or suitable clips at intersections.

All accessories such as chairs and chair-bars are an integral part of the reinforcement and shall be furnished and installed in sufficient quantity to satisfactorily position all steel in accordance with 8110 “Code of Practice for Designs of Reinforced Concrete Structures” or ACI 315, “Manual of Standard Practice for Detailing Reinforced Concrete Structures”.

Except as otherwise indicated on the drawings, bars in slabs, beams and girders shall be spliced in accordance with the table titled "Minimum Lap Splice Lengths" in BS 8110 or ACI315. Splices and laps in columns, piers and struts shall be sufficient to transfer full stress by bond. Splices in adjacent bars shall be staggered if required.

Except as otherwise indicated on the drawings, reinforcement shall be installed with clearance for concrete coverage as per BS 8110 or BS EN 1992-1-1:2004+A1:2014(Euro Code 2) as directed by the Engineer.

All slab reinforcement shall be supported on concrete cubes or wafers of the correct

height. Wafers shall contain soft steel wires embedded therein for fastening to reinforcing. Wafers shall have a minimum compressive strength equal to that of the concrete in which they are to be placed, and shall have been cured as specified for concrete. Masonry units will not be permitted for supporting steel in bottom mats or elsewhere. For supporting the top steel in slabs, the Contractor shall furnish extra steel supports such as channels if required and shall construct blocks of concrete having the same quality as specified for the structure for use in supporting both top and bottom mat steel. Wood blocks, stones, brick ships, cinder blocks, or concrete building blocks will not be allowed. Alternate methods for supporting top steel in slabs, such as vertical reinforcing fastened to bottom and top mats, may be used if approved.

Alternate methods of supporting bottom reinforcement for slabs and beams not exposed to the weather (such as plastic chairs, but not plastic tipped wire) may be used only if specifically approved by the Engineer.

Reinforcement for vertical surfaces (beams, columns, walls) shall be properly and firmly positioned away from the forms at all points by means of stainless steel (tipped) wire or equal, subject to the Engineer's approval.

Reinforcement which is to be exposed for a considerable length of time after being placed shall be painted with a heavy coat of neat cement slurry, if required by the Engineer.

In no case shall any reinforcing steel be covered with concrete until the amount and the position of the reinforcement have been checked by the Engineer and his permission given to proceed with the concreting. The Engineer shall be given at least two days notice of the availability of the set reinforcement for checking.

G. **Straightening Steel**

Reinforcing steel shall not be bent or straightened in a manner that will injure the material. Any use of such injured reinforcing steel will not be permitted.

H. **Approval before Concreting**

All reinforcement, after having been fixed in position, shall be inspected and approved by the Engineer before any concrete is placed. Any concrete placed contrary to this requirement shall, if ordered by the Engineer, be removed together with the reinforcement and replaced by the Contractor at his own expense.

3.1.16 Formwork

A. Formwork design, fabrication and erection shall comply with BS EN 206:2013+A1:2016: 2000 and BS 5975:2008+A1:2011. Formwork shall be designed to withstand the worst combinations of concrete pressure construction and wind loads, together will all incidental dynamic effects caused by placing, vibrating and compacting the concrete in BS 5975:2008+A1:2011.

B. The formwork shall be capable of being dismantled and removed from the cast concrete without shock, disturbance or damage. Where necessary, the arrangement shall be such that the soffit from, property supported on props, can

be retained in position for such period as may be required to achieve the required strength and satisfy the specification.

C. Forms of all cast-in-place concrete shall be made of wood, metal, or other approved material. Wood forms shall be constructed of sound lumber or plywood of suitable dimensions free from knotholes and loose knots. Plywood shall be sanded smooth and fitted with tight joints between panels. Metal forms shall be of an approved type for the class of work involved and of the thickness and design required for rigid construction. All exposed concrete shall be formed with metal or plywood forms.

D. Edges of all form panels in contact with concrete shall be flush within 0.8 mm and forms for plane surfaces shall be such that the concrete will be plane within 0.20 cm each 4 meters. Forms shall be tight to prevent the passage of mortar, water or grout. Forms shall generally be constructed so that the finished concrete conforms to ACI 117 "Standard Tolerance for Concrete Constructions and Materials".

E. Formwork systems shall be designed by a qualified engineer and approved by the Engineer.

F. Forms shall be used for all concrete work, including footings. Forms shall be so constructed and placed that the resulting concrete will be of the shape, lines, dimensions, appearance, and to the elevations indicated on the drawings and conforming to ACI347, "Recommended Practice for Formwork". Whenever so instructed by the Engineer, the Contractor shall submit shop drawings of formed by and design and calculations by Engineer for form work and temporary works at no additional cost to the Engineer for approval. If the Engineer feels that the formwork is in complicated in nature then the drawing and the calculation shall be submitted by a structural Engineer at no additional cost for the form work.

G. Formwork to external faces which will be permanently exposed, all horizontal and vertical formwork joints shall be so arranged that joint lines will form a uniform pattern on the face of the concrete. Where the Contractor proposes to make up the formwork from standard sized manufactured formwork panels, the size of such panels shall be approved by the Engineer before they are used in the construction of the Works. The finished appearance of the entire elevation of the structure and adjoining structures shall be considered when planning the pattern of joint lines caused by formwork.

H. Temporary openings for inspection of the inside of the formwork and for the removal of water used for washing down shall be provided and so formed as to be easily closed before placing concrete.

I. The erected forms shall be watertight from the ingress of motor or grout and egress of internal liquids.

J. The design of formwork shall take into account; height and rate of pour; thickness of member; concrete slump and density; placing temperature; texture of finish; construction joints; wind load.

K. Forms shall be sufficiently rigid to prevent displacement or sagging between supports, under all conditions, and shall be so constructed that the concrete will not be damaged by their removal. The Contractor shall be entirely responsible for their adequacy.

L. Forms shall incorporate 20 mm chamfers on exposed corners of columns, walls and beams, unless otherwise noted on the drawings or where plaster and rendered finish is specified. Similarly chamfer strips shall be provided at horizontal and vertical extremities of all wall placements to produce "clean" separations between successive placements as shown on the drawings.

M. Windows shall be provided in forms wherever directed or necessary for access for concrete placement and vibration. The windows shall be of sufficient size for tremies and vibrators to be placed, spaced at a maximum of 1.8m centres horizontally. Windows shall be tightly closed and sealed before placing higher concrete.

N. Formwork in contact with the concrete shall be treated with suitable non-staining mold oil/ release agent or liquid form coating not having a paraffin base to prevent adherence of the concrete. Care shall be taken to prevent the oil from coming in contact with reinforcement or with concrete at construction joints. Surface retarding agents shall be used only where ordered by the Engineer. Release agents shall not be used where concrete surfaces receive special finishes or applied coatings which may be affected by agent, unless approved by the Engineer.

O. The Contractor shall co-ordinate the work of other sections in forming and setting openings, slots, recesses, chases, sleeves, bolts, anchors and other inserts.

P. Conduits or pipes shall be located so as not to reduce the strength of the construction. In no case shall pipes other than conduits be placed in a slab 125 mm in thickness. Conduits embedded in a concrete slab shall not have an outside diameter greater than 1/3 the thickness of the slab nor be placed below bottom-reinforcing steel or over top-reinforcing steel. Conduits may be embedded in walls provided they are not larger in outside diameter than 1/3 the thickness of the wall, are not spaced closer than 3 diameters on centre, and do not impair the strength of the structure. Embedded pipes and conduits shall be supported independently from reinforcing steel in a manner to prevent metallic contact and thereby prevent electrolytic deterioration. Pipes and conduits where embedded shall be placed as nearly as possible to the centre line of the concrete section. Conduits, piping, and other wall penetrations or reinforcements shall be subject to Engineer’s review and approval.

Q. Form ties or bolts shall be; removable or snap-off metal form ties; cone ends if required by the drawings; designed to prevent formwork deflection and to prevent the spalling of concrete surfaces on removal and shall not be built into the concrete for the purpose of supporting formwork without the prior approval of the Engineer. Where part of a metal tie remains embedded in concrete, it shall not have less cover than reinforcement. Ties shall not leave a hole larger than 10 mm diameter in the concrete surface, when using snap ties. Position ties passing through concrete to approval of Engineer.

R. The Contractor shall ensure that adequate ground support for shoring and supports is available, and if not, shall take measures to make them suitable.

S. Shop drawings shall include plans and sections, giving the following minimum information for each level: details of individual panels, position, size and spacing of adjustable steel shores, position, size and spacing of joists, soldiers, ties, details of formwork for columns, beams, parapets, slab and kickers; details of construction joints and movement joints; details of retaining walls and deep beams showing the position and size of ties, joints, soldiers and sheeting, together with detailed information on erection and casting sequences and construction joints; general assembly details; full calculation sheets; details of all penetrations through concrete; proposed sequence of shoring/re-shoring beams and slabs for different spans and floor heights and number of floors shored, and the stripping time for supported and suspended structural elements, clearly identifying the supported element and suspended element.

T. The Contractor shall allow twenty one days for the Engineer's review.

U. The type of finish will be specified on the drawings or as directed by the Engineer. Before beginning any concrete pour with unformed surfaces, the Contractor shall obtain confirmation of the type of finish required from the Engineer.

V. Before form materials are reused, all surfaces that have been in contact with concrete shall be thoroughly cleaned, all damaged places repaired, all projecting nails withdrawn, and all intrusions or protrusions smoothed.

W. Before placing concrete, the Engineer may inspect the forms, as to condition, cleanliness, joint preparation, and ascertain that all reinforcement and embedded items are adequately supported in the proper location. This inspection shall not relieve the Contractor of his responsibility for the adequacy of the forms or for the completeness and accuracy of embedded items.

X. Holes and seams in the forms shall be such that water and mortar will not escape. Forms in the vicinity of joints shall be retightened just prior to placing the next lift. During concreting, the Contractor shall maintain the forms tight and in position. Any necessary adjustment shall be made immediately.

3.1.17 Nominal Cover

Nominal Cover for Water Retaining Structures shall not be less than 40mm.

3.1.18 Measurement of Ingredients

A All cement used in the production of concrete shall be measured by weight either with an approved weighing machine or by making the size of each batch of concrete such as to require an integral number of complete bags or drums of cement.

B In concrete of Grade 20 or higher, the fine and coarse aggregates shall be measured separately by weigh batching machines which shall provide facilities for the accurate control and measurement of the materials either singly or cumulatively. The machines shall be capable of immediate adjustment by semi-skilled operators in order to permit variations to be made to the mix. All weight dials shall be easily visible from the place at which filling and emptying of the hoppers are controlled.

C Every concrete-mixing machine shall be fitted with a water-measuring device which shall be so constructed that the inlet and outlet valves are interlocked so that either one of them cannot be opened unless the other is fully closed. The device shall be provided with an overflow with a cross-sectional area at least four times that of the outlet pipe and with its discharge point clear off the mixing plant. The entire water system shall be maintained free of leaks at all times. The measuring device shall be fitted with a drain pipe which allows the full quantity of water being measured to be drained off for checking the measurement. The outlet arrangements of the measuring device shall be such that between five and ten percent of the water enters the mixer before the other materials and a further five to ten percent of the water enters the mixer after the other materials. The remainder of the water shall be added at a uniform rate with the other materials. It shall also be readily adjustable so that the quantity of water added to the mixer can, if necessary, be varied for each batch. Arrangements for cooling of the mixing water shall be approved by the Engineer.

D. Any admixtures which may be used shall be measured separately in calibrated and transparent dispensers. Admixture shall be added to the mixture with the water. The dispenser shall be capable of dispensing the agent in quantities varying by not more than 5 percent from the quantities required and in such a manner to ensure uniform distribution of the agent throughout the batch during the time of mixing. The capability of the dispenser to achieve the required dosing and mixing requirement shall be demonstrated to the Engineer and shall be checked each day before concrete mixing commences.

E. The amount of concrete mixed in any one batch shall not exceed the rated capacity of the mixer and the whole of the batch shall be removed before materials for a fresh batch enter the drum. On cessation of work, including all stoppages exceeding twenty minutes, the mixers and all handling plant shall be washed with clean water. All mixing and batching plants shall be maintained free of set concrete or cement and shall be clean before commencing mixing.

F. Contractor shall provide weights, containers and equipment necessary for testing the accuracy of the weighing plant, water-measuring plant and admixture dispenser.

G. The batching plant shall be calibrated each month.

H. Hand mixing of concrete is not allowed.

3.1.19 Mixing of Concrete

A All structural concrete to be placed in-situ shall be manufactured in a computer controlled batching plant. If necessary, the plant shall be complete with suitable water chilling and ice making facility to ensure concrete temperatures are maintained as specified. Batching and mixing concrete off-site shall only be with prior approval.

Mixing and transporting of concrete produced off-site shall be in accordance with the requirements of ready mixed concrete SLS 1144 -1 or BS EN 206: 2013+A1:2016. Concrete shall be mixed in batches in plant capable of combining the aggregates, cement and water (including admixtures, if any) into a mixture of uniform colour and consistency and of discharging the mixture without segregation. On commencing work with a clean mixer the first batch shall contain only half the normal quantity of coarse aggregate to compensate for the adhesion of the other materials to the drum. The natural moisture contents of the aggregates shall be determined before the commencement of each day's concreting and at such intervals during each day as may be necessary. The Contractor shall make due allowance for the water contained in the aggregates when determining the quantity of water to be added to each mix and the amount of water added to each mix shall be adjusted to maintain the constant approved water/cement ratio of the mixed concrete. No concrete shall exceed the specified water/cement ratio. The quantity of water used in mixing shall be the least amount that will produce a workable homogeneous plastic mixture which can be worked into the forms and around the reinforcement. In no circumstances shall the consistency of the concrete be such as to permit a separation of the aggregate from the mortar during handling. Excess water shall not be permitted and any batch containing such excess will be rejected.

B The use of ready-mixed concrete in any part of the Work shall require the Engineer's written approval. The Contractor shall satisfy the Engineer that materials used in ready-mixed concrete comply with the Specification in all respects and manufacturing and delivery resources of the proposed supplier are adequate to ensure proper and timely completion. The specified requirements as to the sampling, trial mixing, testing and quality of concrete of various grades shall apply equally to ready-mixed concrete. Every additional facility, including transport, which the Engineer or persons authorised by him may require for the supervision and inspection of the batching, mixing, testing and transporting to Site of ready-mixed concrete shall be provided by the Contractor. Each load shall be accompanied by a certificate from a batching plant. A copy of the certificate shall be given to the Engineer's site representative for each load. Unless approved otherwise in advance of batching all concrete of single design mix for any one day's pour shall be from a single batch plant of a single supplier. Ready-mix concrete shall conform to BS EN 206:2013+A1:2016, except materials, testing and mix design shall be as specified herein. No water shall be added during transporting to site or at the site. Each mixer truck shall arrive at the job site with its water container full. In the event that a container is not full or concrete tests give a greater slump than acceptable the load shall be rejected. Shade temperature and concrete temperature shall be recorded at the point of discharge of the mixer and at placement for each load of concrete delivered to site. Maximum and minimum temperatures and wet bulb temperatures shall be recorded daily. Perform slump tests in accordance with BS EN 12350-2:2019 at the point of placement for each load delivered to site. Test cement in accordance with ISO 679:2009, ISO 863:2008, ISO 9597:2008, BS 4027 or ASTM C150 for each delivery of cement. Tests of cement and aggregates shall be performed to ensure conformance with requirements specified.

3.1.20 Concrete Testing

A Preliminary (Trial) Test

1 Target mean strength: The concrete mix shall have at least the required minimum cement content and mean strength greater than the required characteristic strength by at

least the current margin. The current margin shall be taken as the lesser of:

a 1.64 times the standard deviation of cube tests on at least 100 separate batches of concrete of nominally similar proportions of similar materials and produced over a period not exceeding 12 months by the same plant and under similar supervision, but not less than one sixth (1/6) of the characteristic strength for concrete of Grade 15 or not less than 3.75N/mm^2 for concrete of Grade 20 or above.

b. 1.64 times the standard deviation of cube tests on at least 40 separate batches of concrete of nominally similar proportions of similar materials and produced over a period exceeding 5 days but not exceeding 6 months by the same plant under similar supervision, but not less than one third of the characteristic strength for concrete of Grade 15 or not less than 7.5 N/mm^2 for concrete of Grade 20 or above.

c If enough data are not available to satisfy the requirements of either (a) or (b) above, the margin shall be taken as two-third of the characteristic strength for concrete of grade 15 or 10 N/mm^2 for concrete of Grade 20 or above. When required characteristic strength approaches maximum possible strength of concrete a smaller margin but not less than 7.5 N/mm^2 shall be permitted. Evidence shall be submitted to the Engineer for each grade of concrete showing that at the intended workability the proposed mixed proportions and manufacturing method will produce concrete of the required quality.

2 To establish the suitability of any material used in the concrete work, unless specified otherwise, the Contractor shall make preliminary tests and prepare design mixes, in accordance with EN 206-1: 2013, in a design laboratory acceptable to the Engineer.

3 In addition to the tests required to establish the suitability of materials, the Contractor shall make one test for each design mix to verify that the total chloride ion content and the total sulphate (SO_3) content of each mix is within the specified limits. Chloride tests shall be performed in accordance with EN 197:2011 and sulphate (SO_3) tests in accordance with EN 197: 2011. Chloride and sulphate levels in the concrete mix shall comply with the following requirements:

	% by wt. of Cement	
Type of Concrete	Chlorides as Cl	Sulphates as $S0_3$
For reinforced concrete		
if made with OPC/MSRPC	max 0.30	max 3.70
if made with SRPC	max 0.06	max 3.70
Pre-stressed concrete and heat-cured reinforced concrete	Max 0.10	max 3.70
For mass concrete		
if made with OPC/MSRPC	Max 0.60	max 3.70
if made with SRPC	Max 0.12	max 3.70

Note:

a. OPC and MSRPC cements can also contain chlorides, the relevant standard EN 197:2011 allows up to 0.1 percent of chloride ion.

b. Any chloride content present in the cement has to be taken into account while computing total chloride ion in the mix.

c. In case the cement contains the maximum limit of 0.1 percent of chloride ion then the aggregates, water and admixtures used for pre-stressed concrete or heat cured reinforced concrete shall absolutely free of chlorides.

4 When the results of a sufficiently large number of tests show that the previously established margin is significantly too large or too small, a change in the current margin used for judging compliance with the specified characteristic strength may be appropriate. Recalculation of the margin shall be carried out as before, but the adoption of recalculated value will not generally be justified if the two values differ by less than 18 percent when based on tests on 40 separate batches or 11 percent when based on tests on 100 separate batches, or 5 percent when based on tests on 500 separate batches. This recalculated margin, if adopted, becomes the current margin for the judgement of compliance with the specified characteristic strength of concrete

B Under the supervision and direction of the Engineer the Contractor will take specimens for cube test, of each class of concrete from different locations on the site. Each set of cubes shall be made at the point of placement. For each grade of concrete a set of six works test cubes shall be made whenever the Engineer may require and not less frequently than as follows:

1 For concrete Grade 35 or 35A or above one set of cubes per 30 cubic metres or part thereof, concreted per day,
2 For concrete Grade 20 one set of cubes per 40 cubic metres or part thereof, concreted per day.

C Works Test Cubes

1 Take test cubes as specified from fresh mixed concrete which is being used in the Works and which has been prepared in the normal way.

2 Cubes shall be numbered consequently and marked with the date, section of work from which they are taken and any other relevant information.

A. Take at least six cubes for each sampling and test 3 at 7 days and 3 at 28 days.

B. Strength of cubes shall be not less than the minimum strength requirements for each type of concrete.

3 If the average strength of the three works test cubes fail at 7 days;
a Immediately stop all concreting until checks are made on material and equipment,
b Immediately rectify any defect which has become apparent as the result of checking,
c At Contractor's option, defective concrete may be removed and replaced without awaiting the 28 day test results.

4 If works test cubes fail at 28 days;
a Suspend concreting operations and do not proceed further without approval,
b Take test cores in accordance with BS EN 12504-1:2019, or conduct

insitu load tests in accordance with BS EN 1881-124:2015 on suspect work, in the presence of the Engineer,

c Replace all defective work,

d Re-testing shall be executed to the Engineer's approval.

D Two cylinders shall be cast to determine the tensile strength of the concrete at 7 days and 28 days, as specified in BS EN 12390-6:2009. Samples shall be taken from every 100 batches, but at least once a week during concreting operations and shall coincide with samples taken for test cubes.

E Concrete shall be tested for durability properties by undertaking absorption and permeability tests where appropriate, or directed by the Engineer, as directed below:

1 Water absorption tests shall be carried out in the laboratory on 75 mm diameter cores cut at an age of 24 to 28 days to enable the tests to be carried out between 28 and 32 days in accordance with BS 1881-122:2011. Upper acceptable limit for absorption after 30 minutes shall be one percent.

2 Permeability tests shall be in accordance with the method described in DIN 1048 and the maximum acceptable penetration at seven days shall be 10 mm.

F Other Tests

1 When instructed by the Engineer, concrete shall be tested for drying shrinkage and wetting expansion. 75 x 75 mm prisms shall be prepared for testing in accordance with Test 5 of BS ISO 1920-8:2009 or EN 772 & EN 771. The maximum acceptable limits shall be 0.05 percent for drying shrinkage and 0.03 percent for wetting expansion.

2 Additional cubes may be required and trials carried out to determine stripping times for formwork; duration of curing and to check testing and sampling errors.

3 Air content of air-entrained concrete shall be determined in accordance with ASTM C231 for each batch produced until consistency has been achieved, when batches may be tested. The maximum value shall not exceed one percent.

G Workability shall be assessed by the tests mentioned hereunder and shall be carried out as required during concreting of permanent works to control workability at the batching plant and at the site of pour. The degree of workability shall be as for the trial mixes and permitted tolerances shall be in accordance with BS EN 206:2013+A1:2016. Slump test shall be performed according to BS EN 12350-2:2019 (at site of pour) and the allowable slump shall be 150 - 175 mm. Compaction factor tests shall be performed according to BS EN 12350-4:2019 (at site laboratory) and the allowable limit shall be 0.85 - 0.92. Vebe time shall be performed according to BS EN 12350-3:2019 (at site laboratory). Flow test shall be performed according to BS EN 12350-5:2019 (at site laboratory).

3.1.21 Transporting Concrete

A Transportation, delivery and handling shall be as specified in BS EN

206:2013+A1:2016. 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 prevent displacement of reinforcement. The Contractor shall ensure that concrete is of the required workability at the point and time of placing. If segregation has nevertheless occurred in any instance the materials shall be remixed to the satisfaction of the Engineer or discarded. No partially hardened concrete shall be deposited. The Contractor shall be responsible for the concrete being placed and compacted within such a time from the addition of the water to the mixer that the previous lift of concrete has not commenced setting.

B Tolerances shall be to BS 5606 for concrete construction and materials.

C The Contractor shall record time, date, temperature and slump of all concrete at the mixer and point of placement. The Contractor shall render to the Engineer, not more than twenty-four hours in arrears, a daily return for each grade of concrete comprising:

1 Number of batches mixed,
2 Number of batches and total volume of concrete placed,
3 Number of batches wasted or rejected,
4 Weight of cement and admixtures used.

D When a truck mixer or agitator is used for transporting concrete to the delivery point, discharge and placing shall be completed within one hour, or before 250 revolutions of the drum or blades, whichever comes first, after the introduction of the cement to the aggregates. Under conditions contributing to early initial set of the concrete, or when the temperature of the concrete is 32°C or above, a time less than 45 minutes will be required.

When non-agitating hauling equipment is used for transporting concrete to the delivery point, discharge and placing shall be completed within 0.5 hours after the addition of cement to the aggregates under normal circumstances and not more than 15 minutes under conditions contributing to easy initial set of the concrete, or when the temperature of the concrete is 30°C or above.

If the above time conditions as to discharge and placing of concrete after introduction of cement cannot be met, the Contractor may be required to use a retarding or a water reducing and retarding admixture. The use of a retarding admixture will be according to ASTM C494 and must be approved by the Engineer, and at no extra cost to the Employer.

The re-tempering of concrete or mortar which has partially hardened and mixing with or without additional cement, aggregate, or water, will not be permitted.

The Contractor shall dispatch trucks from the batching plant so that they shall arrive at the site of the work just before the concrete is required, thus avoiding excessive mixing of concrete while waiting for placing successive layers of concrete in the forms.

Precautions shall be taken in hot weather to prevent loss of slump. Mixer drums shall, when possible, be shaded, lagged and materials shall be kept as cool as possible. For every truck load, the Contractor shall record the slump and the temperature, and obtain the approval of the Engineer.

3.1.22 Placing of Concrete

A No concrete shall be placed until the Engineer has inspected and approved the surfaces upon which the concrete is to be placed, the formwork and the reinforcing steel. The Contractor shall give the Engineer not less than 24 hours to enable this inspection to be carried out. If concrete is not placed within 24 hours of approval being given, approval shall be obtained again before concreting. An inspection shall be made immediately prior to concreting to check the cleanliness of the forms. None of the requirements of this specification shall relieve the Contractor of his responsibility to place in the Works only sound well-compacted concrete free from voids and cracks.

Concrete shall be transported from the mixer trucks by skips, barrows, buckets on cranes, chutes, or conveyor belts. All equipment used to transport concrete shall be clean and free of debris and contaminants. In selecting the method or methods used for transport, consideration shall be given to the effects of the method on the properties of the concrete so as not to result in inferior concrete caused by segregation produced during transport.

Bottom opening skips or buckets shall not be used for transporting over long distances because of the consolidation, bleeding or loss of slump which may result. Buckets or skips shall be capable of free discharge of low slump concrete, with gate mechanisms which permit full control over the discharge with no appreciable segregation.

B The Contractor's staff approved to supervise concrete work shall be on site whenever such work is executed.

C Before placing concrete, the Contractor shall remove from the surface of the foundations or previously placed concrete all oil, Latents, loose fragments of rock, earth, mud, timber and other debris, and standing water to the satisfaction of the Engineer. Unless otherwise specified or directed by the Engineer, all excavated surfaces are to be covered with blinding concrete Grade 20 not less than 75mm thick.

D A vapour barrier separation layer (minimum of gauge 1000 polythene) shall be placed on the underside of blinding concrete and ground slabs on grade as specified. Lap joints shall be minimum 100 mm on sides and ends and the barrier shall not be disturbed while placing reinforcement.

E Concrete shall be deposited so as to maintain a plastic surface approximately horizontal until the completion of the unit. Vertical lifts shall not exceed 60 cm and preferably 45 cm. Vibrators shall be inserted at least 15 cm into the preceding layer if there is such.

Where the placement consists of several layers, each layer shall be placed while the preceding layer is still plastic in order to avoid cold joints. If the underlaying layer has stiffened just beyond the point where it can be penetrated by the vibrator, bond can still be obtained by thoroughly and systematically vibrating the new concrete into contact with the old; however, an unavoidable joint line will show on the surface when the form is removed.

Concrete dropped into place in the Work shall be dropped vertically. It shall not strike the formwork between the point of its discharge and its final place in the Work. Except by prior approval of the Engineer, concrete shall not be dropped freely through a height

greater than 1.5 m. If height exceeding 1.5 m in height, concrete shall be placed using suitable chutes, pipes, hoppers, spouts with restricted outlets, or otherwise, as required or approved by the Engineer. Chutes and conveyor belts shall be also designed so that there is no segregation or loss of mortar.

Chutes shall be U-shaped and of such size as to ensure a continuous flow in the chute. Flat chutes shall not be used. Chutes shall be metal or metal lined and sections shall have approximately equal slopes. The slope shall be not less than 25 degrees and not greater than 45 degrees and shall be such as not to cause segregation of the ingredients. When the placing operation is intermittent, the chute shall discharge into a hopper. Concrete shall be deposited at or near its final position in the placement. Chutes shall be provided with a baffle and down pipe at the discharge end to provide a vertical drop thus minimising segregation.

Concrete shall be provided with a vertical tapered down pipe, trimy or other device, to ensure that concrete is discharged vertically into place.

As far as practicable, pipe shall be kept full of concrete during placing and their lower end shall be kept buried in the newly placed concrete. After initial set of the concrete, the forms shall not be jarred and no strain shall be placed on the ends of reinforcement bars which project.

When pumps are used, the end of the supply pipe shall be kept immersed in the concrete during placing to assist compaction. Concrete shall be carefully placed in horizontal layers which shall be kept at an even height throughout the Work. "Cold Joints" are to be avoided, but if they occur, are to be treated as bonded construction joints by using epoxy to the approval of the Engineer. The application of the epoxy shall be as recommended by the manufacturer. Concrete shall not be allowed to slide or flow down sloping surfaces directly into its final position but shall be placed in its final position from skips, trucks, barrows, down pipes or other placing machines or devices. If this is impossible, it shall be shovelled into position, care being taken to avoid separation of the constituent materials. Concrete placed in horizontal slabs from barrows or other tipping vehicles shall be tipped into the face of the previously placed concrete.

F Mortar or water used at the beginning or end of a run shall be discharged outside the formwork.

G Where concrete abuts against earth or any other material liable to become loose or to slip, care shall be taken to avoid falls of materials on to the surface of the wet concrete by suitable means.

H Concrete toppings shall be placed on top of structural slabs where indicated using a maximum size aggregate of l0 mm, applied over an epoxy bonding agent. All toppings to be steel trowelled finished.

I During the placing of all reinforced concrete, a competent steel fixer shall be in attendance on each concreting gang. He shall ensure that the reinforcement and embedded fittings are kept in position as work proceeds.

J Whenever instructed by the Engineer, the Contractor shall carry out the work in such a manner that the placing of the concrete in any particular section of the structure shall be

executed without any interruption whatsoever from the beginning to the end of the operation. Concrete floor and inverts shall be cast in one layer unless where specified otherwise, or when written approval has been obtained to use an alternative construction method.

K Care shall be taken to prevent men engaged in placing concrete from introducing foreign matter into the concrete from their boots or in any other way. Where concrete, is placed directly against the surface of excavations any softened material shall first be removed. Disturbance of freshly finished concrete shall be prohibited.

M Finished surfaces and slabs shall be protected from the direct rays of the sun to prevent checking and crazing.

When directed by the Engineer to continue placing concrete during times of heavy rainfall, the Contractor shall protect the work by covering to prevent water collecting in pools or washing the concrete surface. Only sufficient area shall be uncovered at a time as will permit the deposition of one load of concrete.

N Placing Concrete in Water

1 No concrete shall be placed in flowing water.
2 Underwater concrete shall be placed in position by tremis, or by pipeline from the mixer.
3 Full details of the method proposed shall be submitted in advance to the Engineer and his approval obtained before placing begins.
4 Where the concrete is placed by the tremis, its size and method of operation shall be in accordance with BS 8004:2015.
5 During, and after, concreting under water, pumping or dewatering operations in the immediate vicinity shall be suspended until the Engineer permits them to be continued.

3.1.23 Hot Weather Concreting

The Contractor shall take precautions to prevent the temperature of concrete rising above 30°C. The concrete temperature shall be maintained at, or below 30°C, until it has hardened, and shall be shaded from direct sunlight to the satisfaction of the Engineer. Concrete shall not be mixed or placed when the ambient shade temperature exceeds 38°C. The times at which concreting will be allowed to take place will be agreed with the Engineer. The Contractor shall take the following precautions in hot weather:

1. Cool mixing by adding ice or chilled water.
2. If ice is used take account in computing water/cement ratios and ensure that ice is melted before the concrete leaves the mixer.
3. Cool aggregate by spraying chilled water and protect aggregate from sunlight with heat reflecting covers.
4. Cool and shade formwork and reinforcement:
5. Use mixed concrete without delay.
6. Do not expose wet concrete, or concrete carrying vehicles to the hot sun for more than the minimum practicable time.(early morning or late evening)

7. Insulate the rotating mixer drum externally to prevent overheating of the metal and excessive heat transfer.
8. Any additional recommendations of ACI-305, BS EN 206:2013+A1:2016 and Cement and Concrete Association advisory note on "Hot Weather Concreting".
9. Concrete shall be placed and compacted before initial set has occurred and in any event not later than sixty minutes from the time of mixing unless otherwise approved by the Engineer.
10. The fresh concrete shall be shaded as soon as possible after placing, and curing by use of fog spray shall be started as soon as the surface of fresh concrete is sufficiently hard.

Concrete placement will not be permitted if, in the opinion of the Engineer, the Contractor does not have proper facilities available for placing, curing and finishing the concrete in accordance with these specifications.

3.1.24 Compacting Concrete

A. Concrete, during and immediately after depositing, shall be thoroughly compacted by means of suitable tools. Internal type mechanical vibrators shall be employed to produce the required quality of finish. Vibrators shall at all times be adequate in numbers, amplitude and power to compact the concrete properly and quickly throughout the whole of the volume being compacted to the satisfaction of the Engineer. Vibration shall be done by experienced operators under close supervision and shall be continued sufficiently to produce homogeneity and optimum consolidation without permitting segregation of the solid constituents. All vibrators shall be supplemented by proper wooden spade puddling approximately adjacent to the forms to remove included bubbles and honeycombs. All vibrators shall operate at not less than 10,000 vibrations per minute (170 Hz) and be of adequate capacity. At least one vibrator shall be available for every 8 cubic meters of concrete placed per hour. In addition, one spare vibrator in operating condition shall be on the site. Particular care shall be taken in the regions of water stops.

Vibration shall be applied at the point of deposit and in the area of freshly deposited concrete. The vibrators shall be inserted and withdrawn out of the concrete slowly. No poker holes shall be left after withdrawal of vibrator. The vibration shall be of sufficient duration and intensity to thoroughly compact the concrete, but shall not be continued so as to cause segregation.

Except for slabs less than 100 mm thick, all concrete placed insitu shall be compacted with power-driven internal type vibrators supplemented by hand spading and tamping. Unless otherwise agreed by the Engineer slabs less than 100 mm thick shall be compacted by approved vibrating screeds. One Spare vibrator in operating condition shall be readily on hand at site in case of breakdown.

B Internal type vibrators shall be inserted into the uncompacted concrete vertically and at regular intervals. Where the uncompacted concrete is in a layer above freshly compacted concrete, the vibrator shall penetrate vertically for about 100 mm into the previous layer. Vibrators shall not come into contact with the reinforcement or the formwork and shall be drawn back slowly from the mass concrete so as to leave no

voids. Internal type vibrators shall not be placed in the concrete in a random or haphazard manner nor shall concrete be moved from one part of the work to another by means of the vibrators.

C Compaction shall commence as soon as there is sufficient concrete to immerse the vibrator and continued during the placing operations so that at no times shall there be a large volume of uncompacted concrete in the formwork.

D The duration of vibration shall be limited to that required to produce satisfactory compaction without causing segregation. Vibration shall not be continued at any one point to the extent that localised areas of grout are formed. Vibration shall, on no account, be continued after water or excess grout has appeared on the surface.

E Vibration shall not be applied directly or through the reinforcement to sections or layers of concrete which have hardened to the degree that the concrete ceases to be plastic under vibration. It shall not be used to make concrete flow in the forms over distances so great as to cause segregation, and vibrators shall not be used to transport concrete in the forms.

F Concrete slabs on the ground shall be well tamped into place. Foundation material shall be wetted, tamped, vibrated, and rolled until thoroughly compacted prior to placing concrete.

3.1.25 Concrete Joints

A Construction joints shall comply with BS EN 206:2013+A1:2016 except as modified here-in. Waterstops are not considered necessary in properly formed construction joints. If the contractor wishes to install waterstops in construction joints to satisfy the requirements of these Specifications, then waterstops shall comply shall be borne by the Contractor. The Contractor shall submit detailed proposals not less than three weeks before the commencement of concreting and the details shall include the sequence of placing concrete; sizes of concrete pours; positions of all vertical and horizontal construction joints; and height of lifts. No concreting shall be started until the Engineer has approved the detailed proposals. Construction joints shall be so located as not to impair the strength of the structure.

Positions of construction joint and size of formwork panels shall be so co-ordinated that, where possible, the line of any construction joints coincides with the line of a formwork joint and that in any case all construction joint lines and formwork joint lines appear as a regular and uniform series. For all exposed horizontal joints and purposely inclined joints, as uniform joint shall be formed with a pattern of approved dimension to give a straight and neat joint line. Concrete placed to form the face of a construction joint shall have all Latinate removed and the aggregate exposed prior to the placing of fresh concrete. Latinate shall wherever practicable be removed by spraying the concrete surface with water under pressure and brushing whilst it is still green or by the application of surface mortar retarder followed by washing and scrubbing with stiff broom. Where the Latinate cannot be removed whilst the concrete is still green the whole of the concrete surface forming part of the joint shall have the aggregate exposed by means of a proprietary power driven scabbling/bush hammer as approved by the Engineer. Powerful hammers shall not be used and hacking, chipping, chiselling, etc. shall not be permitted. All loose matter shall be removed and the exposed surface

thoroughly cleaned by wire brushing, air blasting or washing and the surface to which fresh concrete is applied shall be clean and damp.

Joints shall be located as follows:

1 In the middle third of span in slabs, beams or girders,

2 Walls (vertical) away from corners; spaced at maximum 5m; where the concrete wall is monolithic with the floor or footing, the pouring of the wall shall commence within 7 days of placing the floor slab or footing with which it corresponds. Successive lifts in walls shall be placed within 3 days. Circular walls of tanks with a sliding joint between floor and wall are not subject to the 5 m panel limits referred to above if a lift in the wall is concreted as a continuous ring. Concreting shall then be carried out continuously in both directions until the ring is complete,

3 Walls (horizontal) are only allowed when wall is continuous with floor slab and shall be keyed on cast kicker 150 mm high or on top of wall meeting soffit of suspended members,

4 A minimum 20 mm above soffit of beams connecting or 15 mm above soffits of slabs for columns,

5 Around slabs bearing on ground shall be cast in panels designed by movement subject to 7.5 m panel limits. Where no movement joints are specified or where the distance between movement joints exceeds 7.5 m in any direction for ground slabs and exceeds 7.5 m in length for wall slabs (except as described above under walls) they shall be sub-divided by properly formed construction joints into panels of dimensions not exceeding 7.5 m. Panels shall be separately concreted and, except as detailed below, no panel shall be concreted until the concrete in adjacent panel is at least 14 days old. These requirements will generally be met by casting in alternate bays in a chequer board fashion. If long and short bays are proposed, the long bays shall be concreted first. It is desirable that reinforcing bars extending across in-fill bays are not continuous (i.e. a splice is provided within the in-fill bay). If the Contractor adopts the above or other approved method to accommodate shrinkage, the Engineer may agree to a reduction in the 14 day time, but in no case will the approved period be less than four days. The peripheral ring beam in the floor of a circular tank shall not be concreted in advance of its integral floor slab. The periods referred to above do not apply to successive lifts in walls. The proposed sequence of casting panels as called for in this subsection shall be submitted for the Engineer's approval before commencement of concreting.

6 Non-structural ground slabs shall be cast as ACI 302 and shall be aligned with column or grid lines where practicable.

a Isolation joints shall be diamond-shaped or circular separations around columns ensuring all edges of slabs are isolated from adjoining construction.

b Control joints shall be spaced at 4 to 7m centres in both directions and endent upon the type of coarse aggregate in the concrete

as follows unless reliable data indicate wider spacings are feasible:

siliceous gravel or slag : 4m;
crushed limestone : 5.5m;
crushed granite : 7m.

c Panels formed by joints shall be approximately square and in no case shall be the length/width ratio exceed 1.5:1. They shall be formed by either: sawing a continuous straight line in the top of the slab; grooving fresh concrete with hand grooves; or placing strips of wood, metal or pre-moulded joint material at joint locations. The top edges of strips shall be flush with concrete. Control joints shall extend 1/5 to 1/4 x slab thickness into the slab.

7 Expansion joints: reinforcement or other embedded metal items bonded to the concrete (except dowels in floors bonded on only one side of joints) shall not extend continuously through any expansion joint. Joints shall not be sealed until adjacent concrete is at least 28 days old. Joint sealant shall be prepared and installed in accordance and manufacturer's instructions.

8 Waterstops shall be fixed at locations indicated on the Drawings and shall be installed to give a continuous diaphragm in each joint. Pre-moulded waterstop shall be in maximum possible lengths to minimise the number of end joints. Joints at ends and intersections shall be made in the manner most appropriate to the material used and according to manufacturer's recommendations. Joints shall fully develop effective watertightness, equal to that of the continuous waterstops material; permanently develop not less than 50 percent of the mechanical strength of the parent section; and permanently retain their flexibility. Waterstop shall be fixed to formwork or reinforcement in accordance with manufacturer's recommendations. It shall be fitted accurately to formwork to prevent seepage of grout when concreting and shall not be fixed with nails or ties through the web of waterstop. Damaged waterstops shall be repaired before concreting. Waterstop shall be protected whilst protruding from an incomplete joint.

3.1.26 Concrete Finishes

a. Surface finishes without formwork

The four finishes are intended to be applied as follows;

- **Screeded Finish**

The concrete shall be levelled and screeded to produce a uniform plain or ridged surface as required. No further work shall be applied to the surface unless it is a first stage for a wood float or steel trowel finish.

- **Wood Float Finish**

Following the screeding of the surface to its required level a wood float straight edge shall be worked across the surface to make

sure high spots and depressions are eliminated. Floating shall be continued just long enough to produce a true and smooth surface and if a steel trowel finish is required, to bring a small amount of mortar to the surface.

- **Steel Trowel Finish**

  Surface where appearance is important.

  When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, the surface to the wood float finish shall be steel-trowelled under firm pressure to produce a dense, smooth, uniform surface free from trowel marks.

- **Power Float Finish**

  Surface where a smooth flat finish with only minor deviation is required.

  Any other required finish shall be described in the Contract. Power floating shall be undertaken by steel floating the concrete to an even finish with no ridge or steps. When the concrete has taken a primary set it shall be powered trowelled to a uniform smooth polished surface free from trowel marks or other blemishes. Once power floating is completed the surface finish must be adequately protected from construction traffic.

b. Surface finishes with formwork

The three types of surface finish are consistence with Type A, B and C in Clause 6.2.7.3 of BS 8110: Part 1, and are intended to be applied as follows:

- **Rough Finish**

  Surface next to earth, or to receive further treatment, or of no visual merit, or expressly suitable to their function with workmanship as specified;

  This finish shall be obtained by the use of moulds or properly designed forms of closely-jointed sawn boards. The surface shall be free from substantial voids, honeycombing other large blemishes.

- **Fine Finish**

  Surface required for serviceability and structural soundness and which are not visually important.

  This finish shall be obtained from forms designed to product a hard smooth surface with true, clean arrises. Only very minor surface blemished shall be permitted and there shall be no staining or

discolouration. Any projections shall be removed and the surface made good.

- **Worked Finish**

  Aqueous liquid retaining faces and other surfaces to good quality concrete, required for serviceability, structural soundness and appearance.

  This finish shall be obtained by first producing a fair finish and then filling all surface blemished with a fresh, specially prepared cement and fine aggregate paste whilst the concrete is still green, where possible. After the concrete has been properly cured the faces shall be rubbed down, if required, to product a smooth and event surface. If the surface is to be exposed in the final work, every efforts shall be made to match the colour of the concrete.

  Liquid retaining surface and other surface exposed in the completed Work shall receive a fair forked. All other structural concrete surface shall receive a fair finish.

- Broomed

  Concrete floors and slabs such as bridge decks and pavements where a non-slippery surface is required shall receive, following screeding, a broomed surface. As soon as the condition of the concrete permits, before it has hardened appreciably (and normally within 4 hours after depositing), all water, inadvertent film, crude laitance, and loose aggregate shall be removed from the surface by means of wire or bristle brooms in such a manner as to leave the coarse aggregate slightly exposed and the surface clean and generally in condition to provide a non-slippery surface. The brooms shall "roll" the film and laitance (if any) from the slab and leave it clean. Avoid "muddying" the surface by brooming too soon. Raking shall not be employed, and large depressions and general unevenness shall not be allowed.

  If, in the opinion of the Engineer, the surface finish is not properly done and the resulting surfaces are unsatisfactory, the Contractor shall chip the surface to the satisfaction of the Engineer.

3.1.27 Curing of Concrete

A Curing Compound

Curing compound (for application to exposed surfaces of grout) shall conform to ASTM C-309.

B Curing and Protection

1) The Contractor shall protect all concrete work against injury from the elements and

defacement of any nature during construction operations.

2) All concrete, particularly exposed surfaces, shall be treated immediately after concreting or cement finishing is completed, and shall be provided with continuous moist curing for at least 14 days, regardless of the ambient air temperature. Walls and vertical surfaces may be covered with continuously saturated burlap, or by other approved means; horizontal surfaces, slabs, and other items shall be ponded to a depth of 1.2 cm and kept continuously wet with the use of sprinklers.

3) Finished surfaces and slabs shall be protected from the direct rays of the sun to prevent cracking and crazing.

4) All exposed surfaces shall as finishing proceeds be covered with a wet hessian sheet followed by a reflective polythene sheet. These shall be securely fastened around the edges and supported in order not to damage the finished concrete surface. As soon as practicable the hessian and polythene shall be lowered into close contact with the concrete and securely weighted or fastened down to prevent wind blowing underneath. The hessian sheet shall be maintained in a moist condition at all times and shall be inspected at intervals not exceeding 6 hours. Concrete shall be kept moist on exposed surfaces for a period of not less than 10 days or as approved by the Engineer.

5) Alternative methods of protecting and curing concrete may be approved by the Engineer.

6) Liquid membrane curing shall be an approved non-staining, membrane forming curing compound in accordance with the manufacturer's recommendations and shall be applied immediately after any water sheen which may develop after finishing has disappeared from the surface and within two hours of stripping formwork on formed surfaces. Curing compound shall have a minimum 95 percent moisture retention standard. It shall not be used on surfaces against which additional concrete, or other material is to be bonded, unless it is proven that the curing compound will not prevent bond, or that positive measures are taken to remove it completely from those areas which are to receive bonded applications.

7) In any case liquid curing membranes shall not be used on exposed surfaces or where laitance is to be removed and aggregate exposed to provide satisfactory bond for placing further concrete or mortar screeds. Liquid curing membranes shall not be used where mortar, resin mortar, or joint sealant is to be applied.

8) The maximum and minimum ambient temperatures and humidity shall be measured and recorded each day by the Contractor. The records shall be made available for the Engineer's inspection.

9) When directed by the Engineer to continue placing concrete during times of drizzling rainfall, the Contractor shall protect the work by covering to prevent water collecting in pools or washing the concrete surface. Only sufficient area shall be uncovered at a time as will permit the deposition of one load of concrete. During heavy rainfall concreting is not allowed.

10) Formed surfaces, including the undersides of girders, beams, supported slabs and the like, shall be cured by moist curing with the forms in place for the full curing period, or until forms are removed. When forms are stripped, curing shall be continued by any

applicable specified method.

11) Unformed surfaces shall be cured initially by moist curing and finally by any applicable specified method, unless otherwise indicated.

12) Moisture curing shall be executed by covering surface with water and keeping continuously wet; fine fog water sprays in continuous operations; covering surface with a saturated absorptive cover and keeping continuously wet. The absorptive covers shall be placed with 100 mm laps, to cover the entire surface and edges.

13) Moisture retaining cover curing shall comprise a suitable cover to the concrete surface. The cover shall be in the widest practicable widths and shall have 200 mm side and end laps and shall be sealed with waterproofing tape or adhesive. The Contractor shall immediately repair any holes or tears in the cover with cover material and waterproof tape.

14) Backfill shall not be placed over concrete surround to pipes for a minimum of six hours after completion of concreting and dewatering equipment shall continue in operation for at least this period. Compaction of backfill over the pipe surround concrete shall not commence until at least 48 hours after completion of concreting.

3.1.28 Concrete Inspection

A Concrete work will be subject to detailed inspection and tests at the plant and in the field. The Contractor shall notify the Engineer one day in advance of concrete work for inspections and tests. Sampling of concrete taken from the job will be carried out under the direction of the Engineer. Tests carried out by the Contractor in his site testing laboratory shall be under the direction of the Engineer.

B Concrete shall be produced in accordance with BS EN 206-1: 2000 and this requires that tests are made on the constituent materials in accordance with the relevant British Standard. Control tests are made on concrete to ensure compliance with the specified requirements.

C The Contractor shall establish a plan for sampling and testing to the approval of the Engineer. When tested, the concrete shall meet the appropriate requirements specified in BS EN 206:2013+A1:2016, i.e.:

1 Characteristic compressive strength,
2 Specified mix proportions,
3 Minimum or maximum cement content,
4 Maximum free-water/cement ratio,
5 Workability,
6 Air content of concrete,
7 Temperature of fresh concrete,
8 Density of fully compacted concrete.

D The rate of sampling and testing shall be as specified and/or as directed by the Engineer and the cost of sampling and testing shall be borne by the Contractor. The atmospheric conditions, temperature of concrete, concrete constituents, and the state of reinforcement steel and formwork shall be monitored continuously during concrete

placement.

E The Contractor shall facilitate sampling procedures and provide labour and material as required. The Engineer shall be notified when reinforcing steel is in place in order to facilitate any inspection he deems necessary. The Contractor shall submit checking sheets before placing concrete. Concrete shall not be placed until these inspections have been completed and all deficiencies reported by the Engineer have been corrected to the Engineer's satisfaction.

F The Contractor shall supply all moulds required for tests as described below. Moulds of the same type and manufacture shall be used for making all test specimens. If field tests show excessive slumps or other violations of the specified requirements, the entire batch of concrete from which the sample in question was taken will be rejected. Rejected concrete shall be removed from the site at the Contractor's expense. The Engineer will inspect all concrete operations in the plant and in the field.

G If ready-mix concrete is used, each load of concrete arriving at the job shall be accompanied by a delivery ticket which shall be subject to checking by the Engineer at the plant and which shall contain the following information:

1 Type and strength of the mix of concrete being delivered,
2 Slump and Temperature of the concrete mix,
3 Exact time the cement and aggregate discharged into the delivery truck,
4 The Engineer will reject the load if, upon reaching the job, the concrete cannot be placed within the time limits stated, or the type of concrete delivered is incorrect.

H The Contractor shall keep records of all specimens taken and tests made in a format approved by the Engineer. These records shall be signed by the Contractor and the Engineer.

I Final acceptance of the concrete works is based on twenty eight day testing on the work test cubes. The work is considered in compliance if the average of the three cubes equals, or exceeds, the minimum specified for the class of concrete being placed and if no cube strength falls below 85 percent of the specified works test strength. If the result of the twenty eight day testing is unsatisfactorily, the Contractor, in accordance with the instructions of the Engineer, shall conduct tests in the suspect parts of the structure.

J As and where directed by the Engineer, cylindrical core specimens of 150 mm nominal diameter shall be cut perpendicular to the face of the hardened concrete in the Works for the purpose of examination and testing. The procedure for drilling, examination, measurement and testing for compressive strength shall be in accordance with BS EN 12504-1:2009. Prior to preparation for testing, specimens shall be made available for examination by the Engineer. If the crushing strength of the specimen in accordance with BS EN 12504-1:2009 is less than the minimum crushing strength given in Table 3.3 or if, in the opinion of the Engineer, the concrete fails to meet the specified requirements in other respects, the concrete in that part of the Work of which it is a sample will be considered defective.

3.1.29 Defective Concrete

A Defective concrete shall be defined as one or more of the following:

1 Not conforming to required levels, lines, details and elevations,

2 Defective in required concrete strengths,

3 Defective in appearance in ultimate exposed areas due to:

a Improper placement or preparation of formwork resulting in bowed formwork,

b Improper formwork joints,

c Honey combing,

d Surface cracks or damaged surfaces,

e Exposed reinforcement,

f Improperly placed snap on or cone ties,

g Unsatisfactory conditions for the performance of sandblasting work etc.

B Defective concrete work must be reported to the Engineer. No remedial work shall be performed without the prior agreement of the Engineer, with respect to timing, method of repair, and final acceptable standard and appearance of completed repair work. Defective concrete members shall be totally removed and replaced if a satisfactory appearance (accepting satisfactory strength requirements) cannot be achieved, even after the completion of remedial work and members with satisfactory strength requirements including any adjacent members so effected.

C The Engineer's decision shall be final in all aspects related to the correction of defective concrete.

TABLE 3.0

EN 206:2013+ A1:2016	Concrete specification performance production and conformity.
BS 8500:2015+ A2:2019	Concrete. Complementary British Standard to BS EN 206.

3.1.30 Pressure Grouting

Grout shall consist of a mixture of Portland cement, water, sand, bulk filler, and additives, as specified. Grout mix ratios are expressed in 28 Litre of water to a bag of cement.

The contractor shall perform exploratory drilling as may be required to determine the condition of the rock before grouting and the effectiveness of the grouting operation as the work progresses. All exploratory holes shall be cored and shall be pressure tested when directed by the engineer. Rock core samples shall be carefully placed in correct sequence in labeled core boxes furnished by the contractor. The contractor shall transport the core boxes to the specified location by the Engineer.

Unless otherwise specified, holes drilled through overburden shall be cased with steel. Casings shall be removed after completion of the grouting operations unless otherwise approved by the engineer. Holes in overburden shall be backfilled with grout or a sand-cement mixture or by tamping soil into the holes to approximately the bulk density of the surrounding overburden, unless otherwise specified.

When authorized by the engineer and prior to grout injection, grout holes shall be washed with water and air to remove mud, drill cuttings, and other materials that will interfere with the grout take of the hole. Grout holes to be washed and the sequence of washing shall be approved by the engineer. Washing under pressure using packers or pressure testing shall be performed when specified. Washing time for each hole shall be approved by the engineer.

If mud is moved into a hole by grouting nearby holes after the hole has been washed, the mud shall be removed by rewashing the hole.

The air and water pressure will be adjusted to provide the maximum cleaning condition for the holes. Water and air shall be introduced simultaneously under pressure and at the same elevation in the hole.

Unless approved by the engineer, no holes within 100 feet of a previously grouted hole shall be washed unless the grout has been placed for at least 48 hours.

The contractor shall caulk surface cracks that allow excessive loss of grout. Cracks may be caulked by mechanical means or with fast setting mortar. If necessary, grouting shall be temporarily suspended or the pressure shall be reduced to permit the caulking of leaks. Accelerators may be added to the grout for the same purpose if approved by the engineer.

If grout injected into one hole appears in adjacent holes, the interconnected holes shall be plugged temporarily with packers set just above the level at which the grout is entering. Holes grouted by interconnection shall be split spaced.

The quantity of grout prepared in advance shall be kept to a minimum. Grout that has remained in the mixer or holdover tank with or without agitation for more than an hour shall be discarded.

When the hole shows signs of refusal, a thinner mix shall be used to prevent or remove clogging.

Grouting several holes simultaneously from the same grout pump (multiple header arrangement) is not permitted.

After grouting is completed, the contractor shall remove the grouting plant and all related parts, equipment, and supplies from the site. The cleanup includes unused materials and waste.

Grouting Procedure:

The procedures and grout mixes described below are general guidelines and may be altered in the field by the Engineer to suit the conditions encountered and to meet the design objectives.

Unless on-the-site experience indicates otherwise and in lieu of pressure testing, each stage or lift of a hole to be grouted shall be started with about 0.4 m^3 (three batches) of water: Cement mix to be no thinner than 5:1 (W:C), by volume, unless otherwise.

If the hole continues to take grout at a pumping rate not to exceed 0.08 cubic metre per minute and at a pressure equal to or less than specified as refusal pressure, the mix ratio shall be changed to 3:1 (w:c). If the majority of the holes accept the 3:1 without signs

of slowdown in the rate of take, holes in that stage or location may be started with a 3:1 instead of the 5:1 mix. A change to a different location or stage may require a return to the 5:1 starter mix.

Grout mixes shall be thickened from 5:1 to 3:1 to 2:1 to 1:1 after which sand and/or fly ash shall be added to the mix in a graduated manner. The water-cement ratio shall not be less than one.

3.1.31 Quality

The Contractor shall furnish and place concrete as required by these Specifications. The concrete to be produced and placed shall be of the highest quality and uniformity. The Contractor, in all phases of his operations, will be subject to strict inspection to provide concrete construction of excellent quality. Emphasis will be placed on the uniformity of the concrete aggregate, water-cement ratio, consistency, air content, curing and temperature control of the concrete at the time of placement in the forms.

Where screen sizes for concrete aggregates are shown in United States of America standard sizes, the Contractor may utilise standard screens having metric dimensions closely approximating these sizes as approved by the Engineer.

Consistency of the concrete as measured by the ASTM C143 "Slump of Portland Cement Concrete" shall be as shown in Table 3.1.

TABLE 3.1

Portion of Structure	Slump in cm	Recommended Range
Pavement and slabs on ground	05	2.5-7
Plain footings, gravity walls, slabs and beams	05	2.5-7
Heavily reinforced foundations, walls and footings	7.5	5-10
Thin reinforced walls and columns	7.5	5-10

Concrete shall be of such consistency and mix composition that it can be readily worked into the corners and angles of the forms and around the reinforcement, inserts, embedded items and wall castings without permitting materials to segregate or free water to collect on the surface, due consideration being given to the methods of placing and compacting.

No excessively wet concrete will be permitted and, if at any time, concrete of consistency beyond the limits of Table 3.1 is delivered to the job, the Engineer may reject the concrete or direct the Contractor to add extra cement for which no additional payment will be made. A supply of cement shall be kept available at the site for this purpose. No additional water shall be added at any time (eg. While in transit) except that established for the design. Failure to comply with this requirement shall be justification for rejecting the concrete.

The actual acceptance of aggregates and development of mix proportions to produce concrete conforming to the specific requirements shall be determined by means of prior laboratory tests made with the constituents to be used on the work to achieve the specified objectives of strength and of appearance as defined in 3.1.12.

Well in advance of placing concrete, the Contractor shall discuss with the Engineer the proposed sources of materials and concrete mixes which he proposes to use. He shall furnish samples of aggregate and cement for testing, deliver and test them at his own cost, and shall permit ample time for the laboratory to develop a proposed design mix or to modify the design of the mix within the limits of these specifications to achieve the finished results.

The limiting strengths, water-cement ratios and cement contents, as shown in Table 3.2 shall apply.

TABLE 3.2

Class of Concrete	**Minimum Characteristics Cube Strength at 28 days (N/mm^2)**	**Maximum Water Cement Ratio**	**Minimum Cement Content (kg/cu.m)**	**Maximum Cement Content (kg/cu.m)**
C40	40	0.55	325	400
C35 A	35	0.50	325	400
C35	35	0.60	300	400
C30	30	0.65	275	400
C25	25	0.55	230	400
C20	20	0.55	180	400
C10 (lean concrete)	15	-	-	-

These cement contents apply to "controlled" concrete subject to specific inspection.

If, during the progress of the work, the Contractor desires to use materials other than those approved originally, or if the materials from the sources originally approved change in characteristics, the Contractor shall, at his expense, carry out new acceptance tests of aggregates to establish new basic mixes and obtaining the approval of the Engineer prior to use. Objectionable changes in colour of the structures shall not result from these modifications.

3.1.32 Acceptance Tests

Conformity of aggregates to this specification, and the actual proportions of cement, aggregates, and water necessary to produce concrete conforming to the requirements set forth in Tables 3.1 and 3.2 shall be determined by tests made with representative

samples of the materials to be used for the work. Preparation of samples and tests shall be made at the field laboratory in the presence of the Engineer's designated representative. Representative samples shall be furnished by the Contractor at his own cost.

Cement shall be subject to testing to determine that it conforms to the requirements of this specification. Methods of testing shall conform to the appropriate specification, but the place, time, frequency, and method of sampling will be determined by the Engineer in accordance with the particular need.

Samples of fine and coarse aggregates shall be furnished for examination and testing at least three weeks before the Contractor proposes to use them in the work.
Water content of the concrete shall be based on a curve showing the relation between water content and 7 and 28 day compressive strengths of concrete made using the proposed materials. The curves shall be determined by four or more points, representing an average value of at least three test specimens at each age, and shall have a range of values sufficient to yield the desired data, including all the compressive strengths shown on the drawings, without extrapolation. The water content of the concrete to be used, as determined from the curve, shall correspond to the test strengths of the laboratory trial mixes as shown in Table 3.3.

TABLE 3.3

Concrete Cube Strength, N/sq.mm		
Strength	7 days	28 days
C30 C25 C20	20 16.5 13.2	38.25 32.10 25.94

In no case, shall the resulting mix conflict with the values for maximum water-cement ratios and minimum cement contents as specified in Table 3.2.

3.1.33 Testing of Concrete Cores

If the results for the compressive strength of the concrete used in the Works do not fulfil the requirements in Clause 3.1.35, or if defects of workmanship during construction give rise to doubt as to the strength, durability and/or safety of the structure or of part thereof, supplementary testing may be required to be performed.

At least six concrete cores shall, where ordered by the Engineer, be drilled or cut perpendicular to the face of the hardened concrete and tested in accordance with BS 1881.

The cores shall be approximately 150 mm. in diameter and, where possible, have a height/diameter ratio of two. Where it is not possible to take a core of height/diameter ratio, the appropriate correction factor shall be applied to give the equivalent strength of a cylinder having a height/diameter ratio of two.

If the compressive strength of the cores, adjusted for height/diameter ratio and age, fails to attain the specified characteristic strength at 28 days, the suspected part of the concrete shall be cut out.

3.1.34 Field Tests

Sets of three field control test specimens will be selected at random by the Engineer during the progress of the work, in conformity with ASTM C31, "Making and Curing Concrete Compressive and Flexural Strength Tests Specimens in the Field". The total number of specimens taken on the project may average one set per 20 cubic meters per class of concrete and in general not less than one set of specimens will be taken on any day that concrete is placed. The Contractor shall be responsible for the expenses in taking and transporting the concrete specimens to the laboratory.

The results of the testing shall be conforming to the recommendations given in BS 8007: 1987 “British Standard Code of Practice for design of concrete structures for retaining acquires liquids.” or BS EN 1992-3:2006 “Eurocode 2 – Design of Concrete Structures – Part 3 : Liquid retaining and containment structures” as directed by the Engineer. For Reinforced Concrete Structures other than Retaining Aqueous Liqiuds, shall conform to BS 8110:1997 British Standard Code of Practice for Design of Concrete Structures or BSEN 1992-1-1:2004+ A1:2014 “Eurodode 2 – Design of Concrete Structures – Part 1-1:General rules and rules for buildings as directed by the Engineer.

When it appears that the laboratory cured specimens will fail to conform to the requirements for strength, the Engineer shall have the right to order changes in the concrete sufficient to increase the strength to meet these requirements. The strengths of any specimens cured on the job are intended to indicate the adequacy of protection and curing of the concrete and may be used to determine as to when the forms may be stripped, shoring removed, or the structure placed in service. When in the opinion of the Engineer the strength of the job cured specimens are excessively below those of the laboratory cured specimens, the Contractor may be required to improve the procedures for protecting and curing concrete.

The Contractor shall provide for all costs in the making of such tests including allowing free access to the work for the selection of samples, providing moist storage facilities for specimens, affording protection of the specimens against injury or loss through his operations, and furnishing material and labour required for the purpose of taking and testing samples.

Slump tests shall be made in the field by the Contractor as and when instructed by the Engineer in the presence of the Engineer's representatives.

3.1.35 Measuring Materials

Materials shall be measured by weighing except when otherwise authorised by the Engineer.

The apparatus for weighing aggregates and cement shall be designed and constructed for this purpose, and shall be regularly calibrated. Each size of aggregate and cement shall be weighed separately. The accuracy of all weighing devices shall be such that the successive quantities can be measured to within one percent of the desired amount.

Cement in standard packages (sacks) need not be weighed, but bulk cement and fractional packages shall be weighed.

The mixing water shall be measured by volume or by weight. The water measuring device shall control the volume or weight accurately to 1/2 percent. All measuring devices shall be subject to approval by the Engineer.

Admixtures shall be dispensed either manually with the use of calibrated containers or by an approved automatic dispenser designed by the manufacturer of the specific admixture.

3.1.36 Inspection and Control

The preparation of forms, placing of reinforcing steel, embedment items, conduits, pipes, and sleeves, batch mixing, transportation, placing and curing of concrete shall be subject to the inspection of the Engineer, as well as the testing in the laboratory.

3.1.37 Concrete Appearance

Concrete for every part of the work shall be a homogeneous structure which, when hardened, will have the required strength, durability and appearance. Formwork, mixtures and workmanship shall be such that concrete surfaces, when exposed, will require no finishing.

When concrete forms are stripped, the concrete surfaces when viewed in good light from 6 meters away shall be pleasing in appearance, and shall show no visible defects.

3.1.38 Removal of Forms

The period of time elapsing between the placing of concrete and the striking of form work shall be approved by the Engineer after consideration of the loads likely to be imposed on the concrete, and shall in no case be less than the period shown below.

TABLE 3.4
The minimum period of removing of formwork for concrete where Ordinary Portland Cement is used without admixtures.

Part of Structure	Minimum Period
Sides of foundations, columns, beams and walls	24 hours
Under sides of slabs of up to 4.5 meters span	07 days
Under sides of slabs of above 4.5 metres span and under sides of beams and arches up to 6 metres span	14 days
Under sides of beams and arches over 6 metres span and up to 9	

metres span	21 days
Cantilever slabs and beams	As specified
Domes, shells and other structures of special nature	As specified

If Portland or Sulphate resistance cement of strength class 42.5 or higher is used, table 6.2 of BS 8110-1:1977 shall be applied.

3.1.39 Failure to meet Requirements

Should the strengths shown by the test specimens made and tested in accordance with the above provisions fall below the values given in Table 3.3, the Engineer shall have the right to require necessary changes in proportions to apply to the remainder of the work. As evidenced by core and/or load tests, the Engineer shall have the right to require strengthening or replacement of those positions or portions of the structure which fail to develop the required strength. The cost of all such core borings and strengthening or concrete replacement required because strengths of test specimens are below those specified, shall be entirely at the expense of the Contractor.

When the tests on control specimens of concrete fall below the required strength, the Engineer will permit check tests for strengths to be made by means of typical cores drilled from the structure in accordance with ASTM Methods C42, "Obtaining and Testing Dried Cores and Sawed Beams of Concrete", and C39 "Compression Strength of Molded Concrete Cylinders". In case of failure of the latter, the Engineer, in addition to other recourses, may require at the Contractor's expense, load tests on any slabs, beams, piles, caps, and columns in which such concrete was used. Load tests need not be made until the concrete has aged 60 days.

Slabs or beams, under load test, shall be loaded with their own weights plus a superimposed load of 0.4 times design dead load plus 1.6 times design live load. The load shall be applied uniformly over the portion being tested in an approved manner, and left in position for a 24 hour period and the deflection must not exceed the value:

$$D = \frac{L^2}{20{,}000 - h}$$

Where "L" = a span in cm
"h" = a depth of slab or beam in cm
"D" = a deflection in cm

If the deflection exceeds "D" in the above formula, the concrete shall be considered faulty unless within 24 hours after removal of the load, the slab or beam under test recovers at least 75 percent of observed deflection.

3.1.40 Patching and Repairs

It is the intent to require forms, mixes of concrete and workmanship so that concrete

surfaces, when exposed will require no patching.

As soon as the forms have been stripped and the concrete surfaces exposed, fins and other projections shall be removed; recesses left by the removal of form ties shall be filled; and surface defects, which do not impair structural strength, shall be repaired. All exposed concrete surfaces and adjoining work stained by leakage of concrete shall be cleaned to the approval of the Engineer.

Immediately after removal of forms, the Contractor shall remove plugs and break off metal ties as required herein. Holes shall be promptly filled by: moistening the hole with water, followed with a 0.15 cm brush coat of neat cement slurry mixed to the consistency of a heavy paste. The hole shall immediately be plugged with a 1 : 1.5 mixture of cement and fine aggregate slightly damp to the touch (just short of "balling"). The grout shall be hammered into the hole until dense, and until an excess of paste appears on the surface in the form of a spider web. The surface shall be troweled smooth with heavy pressure.

Form tie holes in the exposed exterior walls and interior walls shall likewise be immediately filled. Extreme care shall be taken to ensure that the colour of the grout used to fill these holes is the same as that of the parent concrete using, if necessary, a mixture of white and grey cement in order to do so.

When patching or repairing exposed surfaces the same sources of cement and sand as used in the parent concrete shall be employed. The colour shall be adjusted if necessary, with the addition of proper amounts of white cement. The surface shall be rubbed lightly with a fine carborundum stone at an age of 1 to 5 days, if necessary, to bring it even with the parent concrete. Care shall be exercised to avoid damaging or staining the virgin skin of the surrounding parent concrete. The surface shall be washed thoroughly to remove all rubbed matter.

Defective concrete and honeycombed areas, as determined by the Engineer, shall be chipped down reasonably square and at least 2.5 cm deep to sound concrete by means of hand chisels or pneumatic chipping hammers. Irregular voids or surface stones need not be removed if they are sound, free of laitance, and firmly embedded in the parent concrete, subject to Engineer's final inspection. If honeycomb exists around reinforcement, the concrete shall be chipped to provide a clear space at least 1 cm wide all around the steel. For areas less than 3.8 cm deep, the patch may be made in the same manner as described above for filling form tie holes, care being exercised to use adequately dry (non-trowelable) mixtures and to avoid sagging. Thicker repairs will require build-up in successive 3.8 cm layers on successive days, each layer being applied as described above. Such repair shall be carried out with the prior approval of the Engineer who will determine whether the defective area is repairable or whether it shall be rejected.

3.1.41 Construction and Expansion Joints

(1) Construction Joints

The Contractor shall submit to the Engineer for his approval, as soon as practicable after the commencement of the Work and not less than one week before the commencement of concreting, shop drawings showing his proposals

for placing concrete on which the position and form of all construction joints and lifts shall be shown. No concreting shall be started until the Engineer has approved the method of placing, the positions and form of the construction joints and the lifts.

The construction joints shall be so located as not to impair the structural strength of the completed structure. The position of construction joints and size of formwork panels shall be so co-ordinated that where possible the line of any construction joint coincides with the line of a formwork joint and that in any case all construction joint lines and formwork joint lines appear as a regular and uniform series. For all exposed horizontal joints and purposely inclined joints, a uniform joint shall be formed with a batten of approved dimensions to give a straight and neat joint line. Rebates, keys or notches shall be formed, and waterstops may be used, at the Contractor's own cost, when deemed necessary or required by the Engineer to complete the water tightness at the joints.

Concrete placed to form the face of a construction joint shall have all laitance removed and the aggregate exposed prior to the placing of fresh concrete. Form retarder may be used to achieve easy removal of the surface concrete with the prior approval of the Engineer. The laitance shall wherever practicable be removed by spraying the concrete surface with water under pressure and brushing while it is still green. While the concrete is still green the whole of the concrete surface forming part of the joint shall be hacked to expose the aggregate. Where aggregate is damaged during hacking it shall be removed from the concrete face by further hacking. All loose matter shall be removed and the exposed surface thoroughly cleaned by the brushing, air blasting or washing, and the surface to which the fresh concrete is applied shall be clean and damp.

Construction joints shall generally be located as follows:

Columns: Joints in columns shall be made at the underside of floor members and at floor levels. Haunches and column capitals shall be considered as part of and continuous with the floor or roof.

Floors: Joints in the system shall be located at or near the middle of the spans in slabs, beams or girders, unless otherwise instructed.

Walls: Vertical joints shall be away from corners. Horizontal joints shall be above splays or openings.

Flat slabs shall be constructed in a checkerboard pattern with alternate bays concreted, adjacent sections being concreted after a period agreed by the Engineer. The contractor shall select the size of the bay such that it will not result in any subsequent cracking due to shrinkage.

(2) Expansion Joints

The Contractor shall submit to the Engineer for his approval, as soon as practicable after the commencement of the Work and not less than three weeks before the commencement of concreting, details of his proposals for the

installation of waterstops. These shall show where joints are to be located and details of the intersections and changes of direction to a scale that shows the position of any joint, or shape of any moulded section.

As far as possible jointing on Site shall be confined to the making of butt joints in straight runs of waterstops. Where it is agreed with the Engineer that it is necessary to make, on site, an intersection, change of direction or any joint other than a butt joint in a straight run, a preliminary joint, intersection or change of direction piece shall be made and subjected to such tests as the Engineer may require.

Flexible water stops shall be fully supported in the formwork, free of nails and clear of reinforcement and other fixtures. Damaged waterstops shall be replaced and during concreting care shall be taken to place the concrete so that water stops do not bend or distort.

3.1.42 Field Control

The Contractor shall advise the Engineer of his readiness to proceed, at least 24 hours prior to each concrete placement. The Engineer will inspect the preparations for concreting including the preparation of previously placed concrete, the reinforcing and the alignment and tightness of the formwork. No placement shall be made without the prior approval of the Engineer.

The Engineer may have cores taken from any questionable areas in the concrete work such as construction joints and other locations as required for the determination of concrete quality. The results of tests on such cores shall be the basis for acceptance, rejection or determining the continuation of the concrete work.

The Contractor shall co-operate in the obtaining of cores by allowing free access to the work and permitting the use of any ladders, scaffolding and such incidental equipment as may be required. The Contractor at his cost shall repair all core holes to the satisfaction of the Engineer.

3.1.43 Sleeves, Pipes, and other Items

The Contractor shall place no concrete until reinforcing steel, pipes, conduits, sleeves, hangers, anchors, and other work required to be built into the concrete have been inspected and approved. All water and foreign matter shall be removed from the forms and excavation. All subgrade below slabs and footings shall be approved by the Engineer before placing concrete.

3.1.44 Equipment Bases

All steel levelling and bearing plates, machinery and other equipment, bearing on concrete surfaces, shall be bedded on non-shrink grout and where necessary, core holes for anchor bolts shall be fully grouted with non-shrink grout. The grout bed shall not be placed until the member has been aligned, levelled, plumbed and finally secured in position.

The exact dimensions for all equipment bases will depend on the dimensions of the

actual equipment furnished. No payment change will be allowed if the dimensions are different from those shown on the drawings.

3.1.45 Non-Shrink Grout

To aid strength and bonding of multiple layer application of grout the Engineer may order the use of non-shrink additive as follows:

TABLE 3.5

Proportions

Material	Volume	Weight
Cement Coarse Aggregate Fine Aggregate	1.0 0.1 1.5	1.0 0.25 1.5
Additives	As recommended by the manufacturer	

Non-shrink grout shall comprise of prepared, size graded aggregate combined with a catalysing agent and water reducing agent. When used in the proportioning of grout, mortar and concrete mixes, shrinkage shall be counter-acted and basic qualities improved. The Contractor shall demonstrate to the Engineer that the product has successfully been utilised on similar projects for a minimum of five (5) years. Preparation of surfaces, mix proportions, application procedures, and precautions shall be followed in strict compliance with the manufacturer's directions.

For very heavy (generally formed) applications, the Engineer may order the addition of pea gravel, passing a 3/8" screen but retained on a 1/4" screen, to the mixture with the proportions modified as follows:

TABLE 3.6

Proportions

Material	Volume	Weight
Cement Coarse Aggregate Fine Aggregate Pea Gravel	1.0 0.2 1.0 1.5	1.0 0.33 1.0 1.5
Additives	As recommended by the manufacturer	

In case where coarse aggregate is employed in multiple layers on exposed faces, the final 1.2 cm shall be composed of the 1:1.5 grout without coarse aggregate.

3.1.46 General Structural Notes

The following general structural notes are to be considered as applicable to all structural drawings:

(1) Structural drawings shall be used in conjunction with civil, architectural, mechanical, electrical drawings; specifications and manufacturer's drawings.

(2) All dimensions and conditions must be verified in the field. Conditions not covered by the plans or specifications shall be brought to the attention of the Engineer before proceeding with construction.

(3) Bar bending schedule for reinforcing steel, pre-cast and pre-stressed concrete members shall be submitted by the Contractor to the Engineer for approval in accordance with the specifications.

(4) Unless otherwise indicated, details shown on any drawing are to be considered typical for all similar conditions.

(5) For size and location of pipe sleeves, see mechanical and electrical drawings.

(6) Size, location of equipment pads and anchor bolts shall be determined by equipment manufacturer and the equipment contractor, as applicable.

(7) Contractor shall be responsible to provide openings for equipment and ducts, whether or not shown on structural drawings.

(8) All concrete footings, slabs, pile caps, shall be placed on a working mat consisting of 10 cm of lean concrete on 10 cm of granular material No.2 unless otherwise shown or noted on the drawings.

(9) Where indicated on the drawings, steel sheeting shall be left in place.

(10) No concrete shall be placed under water or on disturbed native material unless shown otherwise, or permitted in writing by the Engineer.

(11) Backfill behind walls shall be placed as specified and only after slabs supporting walls are in place and concrete has been cured to the design strength.

(12) All concrete construction shall be in accordance with the latest BS codes and manuals.

(13) All reinforcement shall conform to Section 3.2 "Concrete Reinforcement".

(14) Continuous reinforcement shall be lapped in accordance with BS 8110 or ACI 318 and ACI 315 at splices, unless shown on drawings differently.

(15) Spacer bars shall be as noted on drawings but not less than 12 mm diameter at 30 cm spacing.

(16) In concrete beams and girders deeper than 50 cm the contractor shall provide continuous 12 mm diameter bars placed 250 mm centres on each face.

(17) The Contractor shall provide extra bars along each side of openings larger than 30 cm as indicated by typical detail or as shown on drawings.

(18) Main reinforcing steel shall be placed and maintained at the minimum clear distances from surface of concrete as specified in Sub-section 3.2.6 "Installation".

(19) All the exposed concrete edges shall have a 2 cm chamfer.

(20) The use of construction joints at locations not indicated shall be as approved by the Engineer.

(21) All concrete walls of non water retaining structures shall have vertical construction joints spaced not more than 9 meters or as shown on drawings.

(22) No concrete wall of water retaining structures shall have a vertical construction joint.

(23) All concrete walls, slabs and beams shall be built so as to minimise the effect of concrete shrinkage, by placing slabs in checkerboard style, or skipping sections that are to be placed until after the adjoining concrete has had sufficient time to cure.

(24) At least two hours shall elapse after depositing concrete in piers, walls and columns before depositing in beams or slabs supported thereon.

(25) Dovetail inserts shall be provided at 1 m intervals embedded in concrete walls, beams and columns to be faced with masonry.

(26) The Contractor shall be responsible to protect structures against flotation or uplift during construction.

(27) Provide temporary ties and bracing where necessary shall be provided during construction, and until the construction is completed.

(28) Water stops shall be provided in construction joints as specified in Section 3.4 "Concrete Joints" and as indicated on the drawings.

3.2 Pre-Cast Concrete

3.2.1 General

The Contractor shall furnish all labour, materials and plant to perform all work necessary for the product design, fabrication and erection of such reinforced concrete components which by their definition are not normally constructed directly in their final location but elsewhere and installed thereafter as prefabricated units. This

includes all inserts and all material for seating the precast members.

Concrete pipe is specified in "Reinforced Concrete Pipe".

Grouting of joints, making connections and finishing the erected work is also included. All precast concrete work shall be carried out as shown on the drawings, or as directed by the Engineer and as specified herein:

The work included consists of the following:

1. Removable concrete covers
2. Precast concrete curbs
3. Precast concrete chambers
4. Miscellaneous precast concrete units

3.2.1.1 Pre-construction Meeting

A Within a reasonable time prior to commencement of structural precast concrete work, the Contractor shall schedule a pre-construction meeting at a mutually agreeable time with the Engineer and his designated Representatives to discuss design, materials, methods of work and forming systems for structural precast concrete work.

B Prior to this meeting, the Contractor shall submit to the Engineer all pertinent information including:

1 written procedural outlines,

2 description of forming systems,

3 brochures of proposed equipment

4 sources of all materials,

5 characteristics of all materials,

6 the above information shall be received by the Engineer at least 30 days prior to the pre-construction meeting.

C During the pre-construction meeting the Contractor shall present an outline plan for all concrete work to be accomplished and indicating special procedures relative to the structural precast concrete work. The outline shall include:

1 reviews of sources of materials commentary on source,

2 source variations during the course of the work,

3 storage and use of materials,

4 description of all equipment necessary for batching, mixing, conveying, placing, forming, reinforcing, compacting,

5 finishing of structural precast concrete.

3.2.1.2 Qualifications

A Structural precast work shall be executed by an approved specialist Sub-Contractor.

B The Contractor may execute this work himself if he can satisfy the Engineer that he has sufficient experience and expertise in this field and can provide satisfactory evidence that his tradesmen and their supervisory personnel engaged in such work have successful experience with work comparable to that shown and specified. Details of organized quality control and testing procedures shall also be provided.

3.2.1.3 Submittals

A Copies of manufacturer's specifications and installation instructions for each item of proprietary material is used, showing compliance with these Specifications.

B Copies of mix designs with support material, as required by Contract Documents.

C Copies of manufacturer's certificates of mill tests of all cement and reinforcing steel.

D Product Design Criteria and Calculations including loadings for design:

1 Initial handling and erection stresses,

2 All dead and live loads as specified on the contract drawings or as required,

3 All other loads specified for member where they are applicable.

The Design calculations shall be performed by a Structural Engineer experienced in precast concrete design. Calculations for the design of any precast member shall be supported by a statement explaining the principle of design and type of analysis adopted and the influence of any member in achieving the overall stability of the structure shall be considered. Any computer programmes used in the designs shall be fully described and details of input and print out shall be presented in a manner which can be readily understood. Programme manuals and any instruction to programme users shall be made available to the Engineer upon request. Where any such programmes cannot be demonstrated by the Contractor to have been fully checked or where the Engineer considers it necessary, the Contractor shall run such test examples as the Engineer may choose, in order to verify the completeness and accuracy of the programme. Design members exposed to the weather to provide for movement of components without damage, failure of joint seals, undue stress on fasteners or other detrimental effects, when subject to seasonal or cyclic day/night temperature ranges. Design system to accommodate construction tolerances, deflection of other building structural members and clearance of intended openings. Calculate structural properties of framing members in accordance with BS EN 206:2013+A1:2016 and BS 8110.

3.2.1.4 Shop Drawings

1 Layout plans and detailed fabrication and placement drawings for each

structural precast element to be submitted.

2 Shop drawings are to include the following information:
- a Size, grade, profile and dimensions of all materials used,
- b Connection and anchorage details,
- c Lifting devices, locations and handling limitations,
- d Steel reinforcement details,
- e All openings, sleeves, inserts and other provisions in full co-ordination with all trades in the Contract,
- f Identification marks.
- g Detailed outline of sequence and methods of erection.

3 A record shall be kept for every piece of precast element produced showing the following:
- a Type and number
- b Date of pour
- c Concrete test results
- d Reference shop drawing number
- e Type and duration of curing
- f Date of delivery to site
- g Date of fixing in position

4 Copies of all testing and Inspection Reports.

3.2.1.5 Co-ordination

The Work of this section shall be completely co-ordinated with the work of other sections and the Contractor shall verify dimensions and Work of other trades which adjoin or pass through materials of this Section before the installation of items herein.

3.2.2 Quality Assurance

A This Specification Section shall govern all structural precast concrete work for the project except where more stringent or specialized requirements are indicated.

B All work shall be performed to secure for the project homogeneous concrete having the required strength, surface finish, materials, durability, and weathering resistance, without planes of weakness or other structural defects, and free of honeycombs, air pockets, voids, projections, offset of plane and other defacements of concrete.

C The Contractor shall be fully responsible for any defects or damage in the structure or building arising from faulty materials or workmanship and the costs of remedial measures in order to ensure that the completed work complies with the Contract Documents.

D No alterations or substitutions of the structural systems shown on the Drawings shall be permitted unless otherwise specified.

E The Contractor shall supervise and co-ordinate all phases of the structural precast concrete construction process and be responsible for the complete manufacturing process. All methods of manufacture and practices of handling raw materials and manufactured concrete shall be reviewed by the Engineer prior to execution of the structural precast concrete work.

F Only materials of known quality shall be incorporated in the work. All materials shall be properly selected, reviewed and approved by the Engineer before use, and maintained during shipment, storage and use. Construction systems and techniques shall be properly selected, reviewed and approved by the Engineer before use, and maintained throughout the complete structural precast concrete construction phase. Adequate spare equipment, parts, additional components and repair facilities shall be available for all tools and equipment.

G Regardless of approvals by the Engineer, the Contractor shall be responsible for all materials and methods of structural precast concrete work. If any work does not satisfy the Contract Documents the Contractor shall at no additional cost to the Employer implement removal, replacement or remedial work and revise procedures or materials to prevent recurrence of unacceptable work.

3.2.3 Testing and Quality Control

3.2.3.1 Quality Control

A The Contractor shall prepare and provide his quality control programme for structural precast concrete work with particular attention to details, pre-checking processes, procedures and close supervision. In order to assure that proper work is performed to prevent later corrective actions, the Contractor shall provide at least one experienced supervisor full time to provide quality control for structural precast concrete work. The assignment will not relieve the Contractor's other quality control personnel of their duties relative to the quality control of the structural requirements and surface finish of the structural precast concrete work.

B The Contractor shall provide suitable quality control personnel who will be versed in quality control of structural precast concrete work including:

1 materials evaluation,
2 special mix design techniques,
3 mix placement,
4 vibrator selection and use,
5 formwork details formwork protection,
6 release agent use,
7 reinforcing steel,
8 detailing and installation,
9 finishing equipment and techniques,
10 corrective procedures and protection of completed work.

C The Contractor's quality control personnel shall be responsible for verifying all details necessary to produce the final structural design objectives. The Contractor's quality control personnel shall also verify the quality of the structural precast concrete work and guide the production of results which will be within acceptable physical tolerances

3.2.3.2 Testing

A Concrete shall be tested as specified and load tests shall be conducted in accordance with BS 8110 before erection and also after erection.

B The Engineer will evaluate the adequacy of the Contractor's quality control. In addition to the requirements hereinafter specified under Paragraph "MIX DESIGN", the Contractor shall:

1 furnish labour required to facilitate testing,
2 inform the Engineer with at least one day's advance notice when concrete is to be placed,
3 provide storage facilities for concrete test cubes,
4 provide material samples and access to materials as required for testing.

C The Contractor shall station a qualified technician at the batch plant during the entire time of batching, and shall continuously test, inspect, and report on the following:

1 the batching equipment and procedures,
2 the conformance of the materials (cement, aggregates, water and admixtures) to the approved materials,
3 Correct dosage of admixtures as prescribed by the manufacturer are used,
4 the proportioning of the concrete,
5 mix transport equipment.

D Should the batching plant be located more than 500 m away from the site offices, the Contractor shall provide suitable transport, acceptable to the Engineer, for the sole use of the Engineer's staff.

E The Contractor shall station a qualified technician at the casting site to continuously test, inspect and report. The tests shall comprise, for each thirty cubic metres of each different concrete type or portion thereof cast per day, six strength tests as BS EN 12350-2:2019; slump tests; and temperature tests. The Contractor shall check and verify conformance with Contract Documents and approved shop drawings. The Contractor shall check all openings and provisions for full co-ordination with all trades in the Contract as shown on approved shop drawings.

F The Contractor shall provide facilities and equipment for the conducting of all tests specified herein except for the strength test which shall be carried out by an approved independent testing agency.

G All welding of steel supports, anchorages, connections and attachments will be visually inspected by the Engineer.

3.2.4 Materials

A The products and manufacturers specified hereinafter are specified for the purpose of establishing minimum quality. Products equivalent to, or better, than those specified will be considered acceptable. The decision of acceptability will rest with the Engineer.

B All materials shall be provided in accordance with and meet all applicable requirements specified herewith. All cement, aggregates and water shall be provided from single sources, sufficient to complete the entire structural precast concrete work to assure regularity of appearance and uniformity of colour.

C Reinforcing bars shall conform to BS 4449 high strength deformed bars with minimum yield strength of 460 N/mm^2. Reinforcement shall be epoxy coated in accordance with ASTM A 775 M-91 B where shown on the Drawings.

3.2.5 Design Loadings, Actions & Structural Members Selection

A Precast elements shall be designed to withstand all loading conditions against which strength and serviceability must be measured.

B Vertical loads shall include own weight of precast elements, floor covering and live loads indicated on the Drawings.

C Wind pressure shall be calculated in accordance with the provisions of BS 8110 using basic wind speed of not less than 160 km/hr.

D Account must be taken of the loads and deformation caused by temperature and time dependent deformations. For such purpose 55°C temperature variation and 90 percent relative humidity shall be considered for all members, except exterior elements and facade elements where 85°C shall be consider.

E Floor systems are assumed to function as rigid diaphragms with respect to in plane forces. Forces due to lateral loads shall be considered to achieve this assumed condition when designing peripheral beams and continuity ties etc.

F Precast elements shall be designed in accordance with BS 8110. Design tensile stresses shall not exceed the design flexure tensile stress of concrete.

G Nominal cover to steel including links must meet the durability requirement of severe condition of exposure and to meet requirements for two hour period of fire resistance.

H Total deflection of any precast element shall be limited to 1/350 of the span of this element.

I Plans & designs for openings for building services shall be accommodated, where

required or necessary.

3.2.6 Mix Design

A The mix shall be designed to obtain the strength specified. The compressive strength of the structural precast concrete shall be 50 N/mm^2 characteristic cube strength minimum at 28 days and 40N/mm^2 at the time of transfer. The slump shall be 100 mm. Air entertainment shall be 5 percent minimum and 7 percent maximum.

3.2.7 Formwork

A The formwork shall be as required to constantly maintain dimensional and surface finish controls specified in BS 5975:2019. Formed surfaces of the structural precast elements are to be at least as smooth, flat and joint free as 19 mm plywood formed finished.

B Forms shall be constructed of non-staining metal, fibre-glass reinforced polyester, or other approved material. Forms shall be fabricated and reinforced for close control of dimensions, shapes, profiles, curvatures, smooth and perfect edges, and corner finishes and details. Forms shall be sufficiently rigid so that precast units will meet the casting tolerances and shall be constructed tightly to prevent leakage of water or mortar. Form joints will not be permitted on faces exposed to view in the finished work.

3.2.8 Form Release Agent

The agent shall be a quick drying, non-staining type and the manufacturer's supplied solvents shall be used for cleaning re-bars and embedded items.

3.2.9 Bearing Pads

Bearing pads shall be elastomeric neoprene, conforming to Standard Specifications for Highway Bridges (Section 25) adopted by the American Association of State Highway Transportation Officials with maximum compressive stress of 70 kg/sq. cm; maximum shear stress of 7 kg/sq. cm; maximum shear deformation of one half thickness; and maximum compressive strain of 15 percent. Unfactored loads shall be used for design.

3.2.10 Delivery, Storage and Handling

A The structural precast elements shall be removed from the forms without damaging or over stressing and stored or placed for transportation on a stable bed that will not allow further distortion of the member. Stacked members shall be separated with suitable battens and bracing.

B Each member shall be marked with an identifying reference or piece mark, and the date of casting. All piece marks are to be correlated with test reports and plan layouts or erection drawings.

C The structural precast element shall be transported with sufficient battens, bracing, and supports so as not to over-stress by vibration or impact loadings.

D Structural precast units shall be transported, stored and handled in a manner to avoid undue strains, hair cracks, staining, or other damage.

E Units from casting site shall be delivered to the project site in accordance with schedule and proper setting sequence.

F Structural precast units shall be stored free of the ground and protected from wind or rain splashes. Units shall be covered and protected from dust, dirt or other staining materials.

G During fabrication, construction and after erection, the castings shall be protected to avoid possibility of any damage.

3.3 Concrete Finishes

3.3.1 Scope of Work

The contractor shall furnish all labour, equipment and incidentals necessary to finish cast-in-place concrete surfaces as indicated on the drawings and/or specified herein. The finishes herein specified apply to the surface finish of cast-in-place concrete as it is to be in the finished work, and as it is to be finished to receive additional covering such as plastering.

3.3.2 Work Specified Elsewhere

Concrete finish for precast concrete elements is specified in Section 3.5 "Precast Concrete". Painting of concrete, architectural finish coverings, roofing, damp proofing and water proofing are specified elsewhere. Repairs to existing concrete as required to make it suitable for bonding to new concrete or if it is to remain exposed are specified herein.

3.3.3 General

All concrete surfaces including those not exposed in the finished work such as those that are buried or covered by other material interior of pipeline structures (i.e. man-holes) in accessible locations shall have all fins burrs and projections removed. The holes and honeycomb areas shall be filled and patched.

Care shall be exercised to prevent rounding chamfered edges or obliterating the bevel line when removing the forms or doing any other work adjacent thereto.

Dusting of surfaces with dry materials to absorb moisture or to stiffen the mix will not be permitted. Sprinkling as an aid to troweling will not be permitted.

The top surfaces of all concrete including separate concrete toppings and walls shall be

screeded compacted and floated.

The Contractor shall protect the floors from damage after they have been finished by laying protective timbers and minimising traffic over the areas.

3.3.4 Types of Finishes for Cast-in-Place Concrete

(1) Cleaned and Patched

All concrete surfaces regardless as to whether they are exposed or not in the finished work shall be cleaned and patched as specified in sub-section 3.8 "Patching and Repairs".

(2) Vertical Surfaces

Vertical surfaces and the undersides of all slabs and beams shall be finished in accordance with the following schedule unless otherwise indicated on the drawings.

Surface Identification	Type of Finish
Exterior surfaces	Formed
Buried	Carborundum
Exposed	Rubbed
Painted	Rough
Tile, etc.	
Interior Surfaces	
Submerged	Carborundum
Exposed	Rubbed
Tile, etc.	Rough
Painted	Rubbed
Miscellaneous	
Stairs except treads	Carborundum
Equipment pads	Carborundum
Surfaces not readily seen	Formed
Plastered	Rough

(3) Types of Finishes

The following describes the types of vertical finishes:

(a) Carborundum Finish

Surfaces shall be rubbed with cement or carborundum bricks and water to remove form marks, and similar blemishes leaving the surface finish uniformly smooth and washed clean.

(b) Rough Finish

Concrete surface shall be roughened by means of hammering or other means to provide a surface texture that will develop a good mechanical bond. The concrete shall be free from paint, oil, dust or any material that might prevent satisfactory bond. Air and water shall be used to remove loose material. Hammering shall be done by hand or power tools to expose clean virgin concrete (mortar or aggregate) over the entire surface. Not more than 10 percent of the surface (in any unit of area) shall remain unchipped

(c) Rubbed Finish

Immediately upon stripping forms and before concrete has changed in colour, any fins shall be carefully removed with a hammer. While wall is still damp apply a thin coat of medium consistency neat cement slurry by means of bristle brushes to provide a bondingt within any pits or blemishes in the parent concrete; avoid coating large areas of the finished surface with this slurry.

Before the slurry has dried or changed colour, apply a dry (almost crumbly) grout comprising one volume cement to 1-1/2 volume of clean masonry sand having a fineness modulus of approximately 2.25. Grout shall be uniformly applied by means of damp (neither dripping wet nor dry) pads of coarse burlap approximately 15 cm. square used as a float. Grout shall be well scrubbed into the pits to provide a dense mortar in the imperfection to be patched. Allow the mortar to partially harden from one to two hours depending upon the weather. Avoid direct hot sunlight. If the air is hot and dry keep the wall damp during this period using a fine, fog spray. When the grout has hardened sufficiently so it can be scraped from the surface with the perpendicular edge of a steel trowel without damaging the grout in the small pits or holes, cut off all that can be removed with the trowel. Grout allowed to remain on the wall too long will get too hard and will be difficult to remove.

Next allow the surface to dry thoroughly and rub it vigorously with clean dry burlap to completely remove any dried grout. No visible film of grout shall remain after this rubbing. The entire cleaning operation for any area must be completed the day it is started. Never leave any grout on the wall overnight. Allow sufficient time for grout to dry after it has been cut with the trowel so it can be wiped off clean with the burlap. This process removes slight discolorations and stains and gives a uniformly good appearance without effect on a paint coating.

On the day following the repair of pits and blemishes, the walls again shall be wiped off clean with dry used pieces of burlap containing old hardened mortar which will act as a mild abrasive. After this treatment there shall be no built-up film remaining on the parent surface. If, however, such is present, a fine abrasive stone must be used to remove all such material without breaking through the surface film of the original concrete. Such scrubbing shall be light and sufficient only to

remove excess material without working up a lather of mortar or changing the texture of the concrete.

A thorough wash-down with stiff bristle brushes shall follow the final scrubbing operation in order that no extraneous materials remain on the surface of the wall. The wall shall be sprayed with a fine fog spray periodically to maintain a continually damp condition for at least 3 days after the application of the pit repair grout.

Areas larger than 2.5 cm diameter or 1.25 cm deep shall be "day-tamp filled" as for form tie holes. Moisten the hole with water, followed by a 1.6 mm brush coat of neat cement slurry mixed to the consistency of a heavy paste. Immediately plug the hole with a 1:1.5 mixture of cement and sand mixed slightly damp to the touch (just short of balling). Hammer the grout into the hole until dense, and an excess of paste appears on the surface in the form of a spider web. Trowel smooth with heavy pressure.

Employ same source of cement and sand as used in the parent concrete. Adjust colour if necessary by addition of proper amounts of white cement and/or limestone screenings. Rub lightly with a fine carborundum stone at an age of 1 to 5 days if necessary to bring the surface plane with the parent concrete. Exercise care to avoid damaging the virgin skin of the surrounding parent concrete. Wash thoroughly to remove all rubbed matter. If surface ultimately is to be painted, the colour matching may be omitted.

No accelerating admixtures shall be employed in surface treatment. An approved admixture may be utilised (in accordance with the manufacturer's directions) to reduce shrinkage and improve durability of the 1: 1.5 mixture.

(d) Formed Finish

All fins and other projections shall be carefully removed, honey-combing repaired form ties cut out and holes patched all as specified under sub-section 3.9 "Patching and Repairs".

(4) Horizontal Surfaces

The top or final surface of all concrete shall be finished in accordance with the following schedule unless otherwise indicated on the drawings.

Surface Identification	Type of Finish
Floors scheduled to be concrete floor Reservoirs and tanks interiors Exposed roof slabs without built-up roofing	Wood float Light steel trowel Wood float
Exposed roof slabs with built-up roofing Equipment pads Tile	Steel trowel Steel trowel Light steel trowel

Surface Identification	Type of Finish
Vinyl asbestos tile Pavements, walks and ramps Buried roof slabs	Steel trowel Broomed Screeded
Stair treads, interior Platforms Plastering	Broomed Broomed Broomed

3.3.5 **Cement Plastering**

(1) General

Plastering shall consist of portland cement plaster applied to the limits and lines indicated on the drawings. The thicknesses indicated on the drawings are the minimum thicknesses required and additional thickness will be required to provide for any unevenness in the masonry surface. In the event the average complete plaster thickness over an area in excess of 5 square meters will exceed 5 cm, a galvanised wire reinforcing square mesh of weight not less than 1.4 kg/sq. m shall be attached to the masonry and plastered into base coat. Before plastering all grounds and corner bends shall be firmly secured in place. Concrete masonry and brick surfaces shall have sufficient roughness to provide proper bond and shall be dampened by brushing or spraying with clean water followed by a primary coat of portland cement. Where the finished plastering is to be greater than 2 cm thick it shall be applied in two coats, a base course not less than 1.5 cm thick and a finish coat not to exceed 1.5 cm thick.

The base coat of plastering shall be of a mix proportion of 350 kg of cement, and one (1) cubic meter of medium sand. The finish coat shall be in the proportion of 280 kg of cement and one (1) cubic meter of medium sand. Leaner mixes shall only be allowed with the permission of the Engineer. The sand shall be clean, durable particles, free from injurious amounts of organic matter and shall conform to the limits of ASTM C144, "Aggregate for Masonry Mortar."

Before the base coat has hardened it shall be evenly scored to assist in bonding the finish coat. When the base coat has hardened enough to receive the finish it shall be dampened and the finish coat applied. The finish coat shall give the appearance of a rubbed finish herein before specified or as otherwise required to match surrounding surfaces.

Plastered surfaces shall be shielded from the direct rays of the sun for two days and shall be kept moist but care shall be taken not to wash out cement.

(2) Repair of Damaged Concrete

Where concrete is cut and removed to provide for new work, concrete surfaces will be formed which will require finishing. The two surface

conditions considered herein are namely, damaged surface which are to be cleaned and plastered, and exposed in the finished work; and the surface to be incorporated in the new work. The only requirement for damaged concrete surface not to be exposed is that reinforcing steel be cut off flush with the concrete surfaces.

Bonding existing concrete to new structural concrete and damaged concrete against which new concrete is to be placed shall be thoroughly cleaned to remove any loose concrete. Reinforcing steel shall be straightened and incorporated in the new work as required. A neat cement slurry shall be applied to the existing surface just prior to placing new concrete.

Plastering of existing concrete damaged in connection with the new work and exposed to view shall be in conformance with the above specification with the added requirement that a bonding admixture be incorporated into the plastering cement. The bonding admixture shall be an additive to the concrete mix made from natural or synthetic rubber or an organic polymer or copolymers and applied in accordance with the manufacturer's instructions.

3.3.6 Other Surfaces

All exposed edges shall be chamfered as specified on each side unless otherwise noted on the drawings. Care shall be exercised to prevent rounding these edges or obliterating the bevel line when removing the forms or doing any other work adjacent thereto.

3.3.7 Cleaning

All exposed concrete surfaces and adjoining work stained by leakage of concrete shall be cleaned.

3.4 Concrete Joints

3.4.1 General Requirements

(1) Water Stops

All vertical and horizontal joints in concrete slabs and peripheral walls of structures and conduits conveying or containing liquid shall have waterstops, unless specifically noted otherwise on the drawings. This requirement applies to contraction and construction joints in foundation, slabs, and expansion and construction joints in walls and roof slabs.

(2) Suppliers

All concrete jointing elements herein specified shall be furnished by a supplier that can give satisfactory evidence to the Engineer that they are capable of supplying the quantities for the schedule required and has an organisation that is knowledgeable in the installation of these systems. A competent representative of the supplier shall instruct in the installation of these systems.

3.4.2 Materials

Samples of all materials to be furnished under this Section shall be submitted to the Engineer for approval.

(1) Water Stops

These shall be manufactured with high grade polyvinyl chloride. Water stops for expansion joints shall be not less than 24 cm in width dumbbell type with centre bulb, with a minimum web thickness of 9.5 mm. The centre bulb shall have a maximum inside diameter of 1.9 cm and minimum outside diameter of 3.9 cm. The edge rib shall have a minimum diameter of 2.5 cm. All other water stops shall be 15.2 cm dumbbell type with 9.5 mm web and 1.9 cm edge rib diameter. In order to prevent the waterstop folding during concrete pour and assist in keeping waterstop firmly in position, all waterstops shall be provided with steel clips along both edge ribs at a spacing of not more than 50 cm. The waterstop shall be held firmly to the reinforcing steel to the satisfaction of the Engineer with wire of No.12 gauge.

Waterstop shall comply with the following performance requirements:

Tensile strength = not less than 120 kg/cm^2 (by ASTM D638)
Ultimate elongation = not less than 370 (by ASTM D-638)

(2) Premoulded Joint Filler

Premoulded joint filler used with water stops shall have the thickness indicated on the drawings and shall be self expanding cork conforming to AASHO M153 Type III "Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction".

Premoulded joint filler for expansion joint in other locations shall be 1.0 cm thick unless otherwise shown on the drawings and shall conform to AASHO M213-81 "Preformed Expansion Joint Filler for Concrete".

(3) Joint Sealant Filler

The sealing compound used with self expanding cork shall be a two component synthetic rubber compound based on liquid polysulphide comprising BS EN ISO 11600:2003+A1:2011, or polyurethane polymer (non-sag type) which will develop a Shore "A" hardness of 30 after 14 days, and shall be certified by the manufacturer as appropriate for use in the proposed location.

The sealing compound used with premoulded joint filler that is not self expanding cork shall be hot-poured elastic type conforming to AASHO M173-60.

3.4.3 Installation

Water stops for all joints shall be continuous around all corners and intersections. Splices shall be made in accordance with the manufacturer's recommendations, subject to the approval of the Engineer.

Particular care shall be taken to correctly position the waterstop during installation and prevent it being moved or distorted by the concrete placement. The waterstops shall be thoroughly cleaned immediately prior to placing concrete. Adequate provision shall be made to support the waterstop during the progress of the work and to ensure proper embedment, symmetrical about the joint. When PVC waterstops are to be left for future connections they shall be protected by wood covers.

Premoulded joint filler shall be installed at the locations and according to the details shown on the drawings.

Joint sealers shall be placed to the width and depth shown on the drawings. Surfaces in contact with sealers shall be clean, dry and firm with all traces of form oil or other coatings removed. Preparation of surfaces, priming, and the handling and preparation of materials shall be in complete compliance with the manufacturer's instructions.

3.5 Testing of Water Retaining Structures for Water Tightness

Water tightness tests must be carried out on all liquid retaining structures, after installation of pipes or sealed parts through the walls. Concrete structures being supposed to be impervious, test for water tightness shall be carried out by the Contractor to ensure the water tightness.

Testing shall be carried out before any backfill is placed around the concrete structure. If fill has been placed during the test, the Contractor shall take into account of level of groundwater table.

The water tightness test shall be carried out in accordance with Section 9 of BS8007:1987/Chapter 2 of ACI 350-1 as directed by the Employer.

In case of structure with several compartments, each one of them must be filled at the same time and to the same level, and then emptied one by one, in order to observe the behaviour of the partition walls.

3.5.1 Structures intended and designed to be water-retaining (including all tanks, wet wells, basins, reservoirs, channels, sumps, chambers, etc. and any other structures designated as water retaining by the Engineer) shall be tested for watertightness after completion, in accordance with the following method or as directed by the Engineer.

The structure shall be filled with potable water in stages not exceeding one metre in 24 hours. The water level shall be held in stages for such time as the Engineer may require. Should any dampness or leakage occur at any stage, the water shall be drawn off and the defects remedied to the satisfaction of the Engineer.

In the case of structures which are sub-divided into individual tanks, each individual tank shall be tested separately. In the case of underground or semi-underground structures, the testing is to take place before application of water proofing membrane, liner material or any perimeter drain, filter material or backfilling is placed against the walls. In the case of hopper-bottomed tanks, this shall be taken to mean that no material is placed against the vertical external walls of the tank, the sloping walls of the hopper bottoms of the tanks being assumed built direct against the excavation apart from the blinding concrete.

No placing of any material whatsoever against the walls shall take place until the Engineer has given his written approval and acceptance of the water retaining structures as watertight. 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.

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. Notwithstanding the satisfactory completion of the seven 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 by an injection system to the approval of the Engineer. Repairs making the outer face only watertight will not be accepted. The structure shall be re-tested until the watertightness is approved by the Engineer.

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, 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. When the remedial work has been completed in the manner approved by the Engineer, the testing and, if necessary, rectifications shall be repeated until a satisfactory test is achieved. 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, in accordance with the Conditions of Contract.

All expenses involved in the satisfactory water-tightness testing of all the water retaining structures in the Works shall be included by the Contractor. 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.

3.5.2 After completion and cleaning of the structure and all associated pipework, if any, the Contractor shall fill the structure up to the top water level and leave for a stabilizing period of 21 days in order to allow for absorption and autogenous healing to take place. Water shall be added over this period to maintain the top or high water level. The Contractor shall ensure that all pipes and specials are available in ample time ahead of testing.

Two sets of evaporation trays shall be provided along with two sets of rain gauges. Levels in the trays and structure shall be made and recorded by a hook gauge with vernier attachments. Before and during testing, flows in the structure underdrainage, if any, shall be monitored, measured and recorded. Each underdrain shall be numbered and observations reported by underdrain number to facilitate analysis of the data.

On the twenty second day, two shallow watertight evaporation trays of area 0.4 sq. metres shall be filled with 75 mm of water and placed to float in the structure. The water level in the structure shall be recorded and the test commenced and carried out over the next seven days. Readings of water levels in the structure and trays shall be made and recorded every 24 hours over this period. If the water level in the tank falls or any other sign of leakage occurs by the end of the test period then the Contractor shall search and mark all areas of defect. The structure shall then be emptied and the defects made good as specified herein.

After completion of remedial measures the structure shall be refilled and the test repeated. This process shall be repeated until the structure is watertight to the satisfaction of the Engineer. The fall of water level in the structure over the test period of seven days, minus the fall accounted for by evaporation and rainfall shall not exceed 1/500 of the average water depth of the full structure or 10 mm whichever is less.

The roofs of structures shall be tested for water tightness before laying of any roof membrane. Roof and fittings shall be hosed down vigorously and this shall be repeated in such a way as to keep the roof wet for three successive days. Roof and fittings shall be deemed satisfactory for water tightness if no discernible leaks or damp patches show in the soffit. Roof covering shall be completed as soon as possible after testing.

3.6 Patching and Repairs

Remedial Treatment of Concrete Surfaces

Any remedial treatment to concrete surfaces shall be agreed with the Engineer following inspection immediately after the stripping of formwork and shall be carried out without delay.

Any concrete the surface of which is found to have been treated before inspection by the Engineer shall be rejected.

Any minor surface blemishes shall be repaired to the satisfaction of the Engineer immediately after completion of curing. Remedial measures may include, but shall not be limited to, the following:

(a) Holes left for formwork supports shall be thoroughly cleaned out to remove all loose material and the sides shall be roughened, if necessary, to ensure a satisfactory bond. They shall then be filled with drypack mortar.

(b) Fins, pinhole bubbles, surface discoloration and minor defects may be rubbed down with sacking and cement immediately the formwork is removed.

(c) Abrupt and gradual irregularities may be rubbed down with carborundum and water after the concrete has been fully cured.

(d) Small defects and minor honeycombing shall be chipped out perpendicular to the face of the concrete to a depth of at least 25 mm. and filled with drypack mortar as specified.

All other defects will be regarded as too extensive to permit satisfactory repair and the concrete containing the defect shall be broken out and replaced.

It is the intent to require forms, mixes of concrete and workmanship so that concrete surfaces, when exposed will require no patching.

As soon as the forms have been stripped and the concrete surfaces exposed, fins and other projections shall be removed; recesses left by the removal of form ties shall be filled; and surface defects, which do not impair structural strength, shall be repaired.

All exposed concrete surfaces and adjoining work stained by leakage of concrete shall be cleaned to the approval of the Engineer.

Immediately after removal of forms, the Contractor shall remove plugs and break off metal ties as required herein. Holes shall be promptly filled by: moistening the hole with water, followed with a 0.15 cm brush coat of neat cement slurry mixed to the consistency of a heavy paste. The hole shall immediately be plugged with a 1 : 1.5 mixture of cement and fine aggregate slightly damp to the touch (just short of "balling"). The grout shall be hammered into the hole until dense, and until an excess of paste appears on the surface in the form of a spider web. The surface shall be troweled smooth with heavy pressure.

Form tie holes in the exposed exterior walls and interior walls shall likewise be immediately filled. Extreme care shall be taken to ensure that the colour of the grout used to fill these holes is the same as that of the parent concrete using, if necessary, a mixture of white and grey cement in order to do so.

When patching or repairing exposed surfaces the same sources of cement and sand as used in the parent concrete shall be employed. The colour shall be adjusted if necessary, with the addition of proper amounts of white cement. The surface shall be rubbed lightly with a fine carborundum stone at an age of 1 to 5 days, if necessary, to bring it even with the parent concrete. Care shall be exercised to avoid damaging or staining the virgin skin of the surrounding parent concrete. The surface shall be washed thoroughly to remove all rubbed matter.

Defective concrete and honeycombed areas, as determined by the Engineer, shall be chipped down reasonably square and at least 2.5 cm deep to sound concrete by means of hand chisels or pneumatic chipping hammers. Irregular voids or surface stones need not be removed if they are sound, free of laitance, and firmly embedded in the parent concrete, subject to Engineer's final inspection. If honeycomb exists around reinforcement, the concrete shall be chipped to provide a clear space at least 1 cm wide all around the steel. For areas less than 3.8 cm deep, the patch may be made in the same manner as described above for filling form tie holes, care being exercised to use adequately dry (non-trowelable) mixtures and to avoid sagging. Thicker repairs will require build-up in successive 3.8 cm layers on successive days, each layer being applied as described above. Such repair shall be carried out with the prior approval of the Engineer who will determine whether the defective area is repairable or whether it shall be rejected.

3.7 **DryPack Mortar**

Drypack mortar for filling holes and repairing surface blemishes shall be made from one part by weight of cement and three parts fine aggregate passing a 1 mm. sieve and an expanding agent approved by the Engineer. Additives to improve workability may be added to the approval of the Engineer. The colour of the mortar shall match that of the surrounding concrete. The mortar shall be mixed with only sufficient water to make the materials stick together when being moulded in the hands.

The drypack material shall be placed and packed in layers having a thickness not greater than 15 mm. The compaction shall be carried out by use of hardwood stick and hammer and shall extend over the full area of the layer, particular care being taken to

compact the drypack against the sides of the hole. After compaction the surface of each layer shall be scratched before further loose material is added. Holes shall not be over filled and the surface shall be finished by laying a hardwood block against the drypack fill and striking the block several times. Steel finishing tools shall not be used and water shall not be added to facilitate finishing.