FINAL

Upgradation of the existing liquid jetty to handle VLGC vessel

Technical Specification –
Part A Concrete and Reinforcement

Client: Gujarat Pipavav Port Limited

Reference: DI1466-RHD-P2-MA-SP-CM-0901

Status: S4/P03

Date: 07 June 2021

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HASKONINGDHV CONSULTING PVT. LTD.

Platinum Techno Park 502-505
5th floor Plot No. 17 & 18
Sector 30 A, Navi Mumbai 400 703
Maharashtra
India
Maritime & Aviation
CIN: U93000DL1997PTC089958

+91 22 4161 5000 **T**
+91 22 4161 5050 **F**
info.india@rhdhv.com **E**
royalhaskoningdhv.com **W**

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1 Introduction

1.1 Purpose and Scope

This document defines the requirements for the design, supply and construction of concrete and steel reinforcement for use in the Works.

1.2 General

All materials used in the Works shall be new unless approved otherwise by the Engineer.

The Contractor may propose the use of recycled products where it deems appropriate, provided that there is no detrimental impact to the performance or durability of the Works.

All materials used in the Works shall be sampled and tested in accordance with the relevant codes and standards, and as specified in the Employer's Requirements.

In case of any conflict between the relevant codes and standards and the Employer's Requirements, the most onerous criteria shall apply.

All materials shall be stored and handled in accordance with instructions and directions of the manufacturer (where relevant), and always in such a way to prevent damage and/or deterioration of the materials.

1.3 Hazardous Materials

The use of hazardous materials shall be avoided wherever possible and minimised to the maximum possible extents.

All hazardous materials shall be clearly identified, and the relevant material data sheets shall be included in the Project Data Book (as specified in PER#001 Part B "Documents on Completion").

1.4 Applicable Codes

This technical specification is based on Indian Standards and Eurocode standards including but not limited to those listed below; Indian Standards shall generally take precedence unless specifically referenced otherwise in this Employer's Requirements or directed by the Engineer:

IS 456: Plain and reinforced concrete – Code of practice
IS 13920: Ductile detailing of reinforced concrete structures subjected to seismic forces – Code of practice
IS 12269: Ordinary Portland Cement, 53 Grade – Specification
IS 3812: Pulverized fuel ash – Specification
IS 12089: Specification for granulated slag for the manufacture of Portland slag cement
IS 383: Specification for coarse and fine aggregates from natural sources for concrete

IS 1903: Concrete admixtures – Specification
IS 1199: Methods of sampling and analysis of concrete
IS 516: Methods of tests for strength of concrete
SP23: Handbook on concrete mixes (Bureau of Indian Standards)
IS 4925: Concrete batching and mixing plant – Specification
IS 1786: High strength deformed steel bars and wires for concrete reinforcement – Specification
IS 2502: Code of practice for bending and fixing of bars for concrete reinforcement
IS 14687: Falsework for concrete structures – Guidelines
EN 1992: Eurocode 2 Design of concrete structures
EN 197-1: Cement: Composition, specification and conformity criteria for common cements
EN 206-1: Concrete: Specification, performance, production and conformity
EN 1008: Mixing water for concrete. Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete.
EN 12350: Testing fresh concrete
EN 12390: Testing hardened concrete
EN 12620: Aggregates for concrete
EN 13670: Execution of concrete structures
EN 13791: Testing concrete
BS 6349: Maritime works

2 Scope of Works

This document specifies the minimum requirements related to concrete and reinforcement intended for use in unreinforced and reinforced concrete structures including precast and/or in situ concrete.

This document does not consider repairs to degraded reinforced concrete structures.

This document shall be read always in conjunction with PER #001 “General” (all parts), PER #002 “Materials” (relevant parts) and PER#006 “Yard Civil and Structural” (relevant parts), plus other PER documents as referenced herein.

3 Material Specification

3.1 Concrete – General

3.1.1 Components

Standard concrete shall consist of Portland Cement (PC), clean fine and coarse aggregate, clean water and mineral admixtures (e.g. cementitious replacements), chemical admixtures and ice as required by the Drawings and the Contract.

All concrete mix designs and material components shall be subject to review by the Engineer.

3.1.2 Conformity

The Contractor shall submit to the Engineer certificates attesting to the conformity of all Materials to all applicable standards.

All materials shall be tested as required by the Employer's Requirements to ascertain their suitability for use in the Works. The cost for all such testing shall be deemed to be included in the Accepted Contract Amount.

3.1.3 Environment

To provide robust and site-specific concrete structures, the Contractor shall ensure the following issues are addressed in the Works:

1. Environmental conditions e.g. exposure to chlorides, abrasion, etc.
2. Available materials e.g. aggregate characteristics, cementitious replacement materials, reinforcement sizes, etc.
3. Suitability of the selected construction methodology e.g. concrete pump vs. crane, underwater concrete placement, reinforcement laps vs. couplers vs. welding, etc.
4. Anticipated maintenance regime and design life of the structure
5. Health and safety for the Contractor's Personnel, Employer's Personnel and other sub-Contractors.

The Contractor shall ensure the concrete mix design(s) and construction methods are suitable to restrict concrete degradation mechanisms including but not limited to:

1. Chloride permeation
2. Carbonation
3. Sulphate attack
4. Abrasion
5. Delayed ettringite formation

The use of coatings and/ or impregnations for concrete repairs is acceptable, subject to the Engineer's review.

Coatings/ impregnations may be employed as a supplement to, but shall not be a substitute for, appropriate designs, materials, etc. for new construction.

Stainless steel reinforcement shall not be used.

Epoxy-coated or galvanized reinforcement shall not be used.

3.2 Cement

3.2.1 Permitted types of cement:

Type	Standard Specification
Portland Slag Cement	IS - 455 with slag content more than 50% but less than 65% of the Portland Slag cement. Slag shall be Grade 80 slag with max Blaine surface area = 4400 cm^2/g.
Ordinary Portland Cement (OPC)	Grade 53 to IS: 12269 Grade 43 to IS: 8112
Portland Pozzolana Cement (PCC) (Calcined Clay Based)	IS: 1489 (Part 2)
Portland Pozzolana Cement (PCC) (Fly Ash Based)	IS: 1489 (Part 1)

Alternative or additional mineral admixtures such as limestone and silica fume may be proposed for the Engineer's review, with appropriate justification such as local cement availability, improved performance, etc.

3.2.2 Approval of Cement Supply

Supply of cement for the Works shall be arranged by the Contractor.

So far as is possible cement of a required type shall be supplied from only one source throughout the execution of the Works, and no variations in source of supply shall be made without the approval of the Engineer.

The approval of the Engineer to any type of cement shall not relieve the Contractor his responsibility and at any time the Engineer may give notice for removal of any consignment of cement from the Site if such consignment does not in every way comply with the requirements of this Specification.

Before any cement is ordered or brought on to Site, the Contractor shall submit to the Engineer for his approval a detailed list of the sources / manufacturers and manufacturer's brand names of all types of cement which he proposes to use in the Works.

This shall be accompanied by full details of the composition and properties of cement, as set out in the Cement Properties Table. This shall be completed for each type of cement and for each proposed source / manufacturer.

3.2.3 Manufacturer's Cement Test Certificates

Manufacturer's Cement test certificates shall be furnished to the Engineer for all consignments of cement and no cement shall be used in the Works until the Engineer has been satisfied that it has been tested and complies with the relevant standard specifications.

3.2.4 Sampling and Testing of Cement

Notwithstanding the submission by the Contractor of the information detailed above, the Engineer may at any time order any further tests which he considers necessary for the purpose of establishing the true quality of the cement proposed and the concrete produced there from, under actual Site conditions and with the aggregates proposed by the Contractor, before giving his approval to any cement.

Any consignment of cement delivered to the Site may be subject to testing, if directed by the Engineer. Cement in storage may also be subject to testing to check that it has not deteriorated. Cement which is not used within 90 days from its date of manufacture shall be tested. Samples shall be taken by the Engineer from different containers and he will despatch them to a laboratory approved by him. The charges towards such testing shall be borne by the contractor.

The cement from the consignment from which the samples have been extracted for testing shall not be used in the Works before completion of testing and analysis and until it has been accepted as satisfactory by the Engineer.

Should the results of any of the tests provided for in this Clause show that any sample fails to meet the minimum requirements of this Specification, the whole consignment to which the sample belongs shall be rejected and be removed from the Site at the Contractor's cost.

No cement from any consignment shall be used in the Works without the approval of the Engineer.

3.2.5 Failure to Supply Certificates or Carry Out Tests

Failure to comply with either of Clauses 3.2.3 and 3.2.4 will render liable to rejection by the Engineer all work containing unapproved cement.

3.2.6 Delivery of Cement

The cement shall be delivered to the Site in such consignments as shall ensure satisfactory progress of the Works.

Except where bulk delivery is approved, cement shall be packaged by the manufacturer in bags or containers that are so designed as to prevent any contamination and to minimise loss of Contents and the adverse effects of moisture and high humidity during transportation and storage.

All bags and containers shall be delivered sealed to the satisfaction of the Engineer. Each shall be adequately and permanently marked with the manufacturer's name, the cement type, the standard specification to which it was made, the date of manufacture or date code and batch number, so as to enable correlation to be made of every part of each consignment with the relevant test certificates and delivery notes.

Cement, when being conveyed to the Site in lorries, vessels or other vehicles, shall be properly protected from the weather and from contamination of any kind. Any cement which proves to have been damaged or contaminated in transit will be rejected upon delivery.

Cement delivered in split bags or containers will be rejected.

Where cement is being imported the Contractor shall supply the following details for all shipments intended for delivery to Site: date of manufacture, date of original loading, destinations en-route, date of unloading and intended date of delivery to site.

Where bulk cement deliveries are proposed the Contractor shall obtain the prior consent of the Engineer to the method of delivery and shall provide all information required by the Engineer concerning off-site storage and loading arrangements. He shall also provide reasonable facilities for the Engineer to inspect these arrangements for approval and routine inspection purposes. The temperature of cement delivered in bulk shall not exceed 65ºC.

3.2.7 Storage of Cement

Bulk cement shall be stored in bins or silos that provide complete protection from dampness, contamination and minimize cracking and false set.

Cement bags shall be stored on pallets in dry enclosed sheds or other structures (storage under tarpaulins shall not be permitted), well away from the outer walls and insulated from the floor to avoid contact with moisture from ground and so arranged as to provide ready access. Where excessive concrete temperatures may occur, cement shall be stored in such a manner as to minimise temperature increases from solar radiation (solar gain).

Damaged cement bags shall not be used and shall be removed from Site.

Cement stored for ninety (90) days or longer before use shall be tested at a certified an accredited testing laboratory to ascertain its suitability for use in the Works.

Cement shall be adequately protected at all times from rain and spray. Cement which has set or partially set shall not be used in the Works. Price quoted shall be deemed to be inclusive of the above requirements.

Storage under tarpaulins shall not be permitted.

At any time, should the Engineer consider that any cement is defective, then irrespective of its origin and/or manufacturer's test certificate, it shall be tested at an accredited testing laboratory. Until the test result is found to be satisfactory, the cement shall not be used in the Works.

3.3 Aggregate

3.3.1 General

All aggregate shall conform to IS 383.

All fine and coarse (>4.75mm) aggregates proposed for use in the Works shall be subject to the Engineer's review and the sources of supply shall not be changed without the Engineer's prior review.

In the event that rounded river gravels are the only source of concrete aggregates available, the Contractor shall ensure that a percentage of the rounded gravels are crushed, such that the final grading of the aggregate is in accordance with the required aggregate grading S-curve. The crushed aggregates shall achieve suitable interlock as required to achieve the strength grade of the concrete. A representative sample of the approved aggregate mix shall be maintained at the concrete batching facility to ensure ongoing compliance with the agreed rounded and crushed aggregate proportions.

Aggregates shall consist of natural sand, crushed stone and gravel from sources known to produce satisfactory aggregate for concrete.

Aggregates shall be chemically inert, strong, hard and durable against weathering, of limited porosity and free from deleterious materials that may cause reinforcement corrosion and/or that may impair the strength and/or durability of concrete.

The aggregate grading shall produce a dense concrete of the specified strength and consistency that can be readily worked into position without segregation and shall be based on the mix design and preliminary concrete tests as detailed in the Employer's Requirements.

Aggregate with specific gravity (saturated surface dry) less than 2.6 shall not be used.

Reclaimed aggregate shall not be used.

Sea-dredged aggregate shall not be used.

3.3.2 Fine Aggregate

Fine aggregate, for other than lightweight concrete, shall consist of natural sand and/or crushed stone sand conforming to the applicable Standards.

Crushed sand shall be acceptable provided the constituent rock/ gravel composition is sound, hard, dense, non-organic, uncoated and durable against weathering.

Fine aggregate shall be screened and/or washed as necessary to remove all objectionable foreign matter and to separate the sand to the required size fractions.

Fine aggregate shall be clean and free from dust, organic matter, adherent coating, clay, organic matter, alkalis, mica, salt or other deleterious substances that might be injurious to the setting qualities, strength or durability of concrete.

3.3.3 Coarse Aggregate

Coarse aggregate shall consist of natural or crushed stone and gravel conforming to the applicable Standards.

Coarse aggregate shall be angular in shape and have predominately granular or crystalline (fracture) surfaces.

Coarse aggregate shall be clean and free from elongated, flaky or laminated pieces, adhering coatings, clay lumps, coal residue, clinkers, slag, alkalis, mica, organic matter or other deleterious matter.

Crushed rock shall be screened and/or washed for the removal of dirt or dust coating, if so required to adhere to the requirements of the Employer's Requirements.

Coarse aggregates shall be well graded and shall conform to limits specified in IS 383.

The nominal maximum aggregate size shall not exceed 5mm less than the minimum clear distance between reinforcing bars or 5mm less than the minimum cover to the reinforcement, whichever is smaller.

The maximum size of coarse aggregate shall conform to the maximum size specified above but in no case shall it be greater than 25% of the minimum thickness of the member, provided that concrete can be placed without difficulty to surround all reinforcement thoroughly and fill formwork corners.

3.3.4 Aggregate Storage

All aggregates shall be stockpiled separately on Site or within properly constructed bins to avoid intermixing of different aggregates.

Contamination of aggregates by foreign material and/or soil shall be prevented by methods accepted by the Engineer e.g. by storing aggregates within hoppers or on concrete slabs with dividing walls to prevent mixing of aggregate grades.

Segregation of aggregates shall be prevented, and segregated aggregates shall not be used.

Rejected segregated aggregates may be used after remixing, provided that test results show compliance with the required gradation.

Where excessive concrete temperatures may occur, aggregates shall be stored in such a manner as to minimise temperature increases from solar radiation (solar gain).

Stored aggregates may be watered to stabilise moisture content and temperature.

3.3.5 Sampling of Aggregates

Each size of aggregate from each source shall be sampled as specified in IS 2430 at the discharge points on the production plant (i.e. conveyors or hoppers, NOT stockpiles) at three well-spaced time intervals during the course of each of three consecutive production days. These samples shall be designated as Production Samples.

In addition, selected samples shall be taken from producer's stockpiles or materials ready for loading which indicate any readily visible variations in physical characteristics, or appearance. These samples shall be designated as Stockpile Samples.

All samples shall be taken in the presence of the Engineer, if he so requires, and shall be tested as required below.

Representative portions of the above samples which have been tested in accordance with Clause 3.3.6 shall be taken for reference purposes and shall be split and retained on site by both the Contractor and the Engineer to act as control samples for comparison with later deliveries.

3.3.6 Grading of Aggregates

Coarse Aggregate:

The maximum size of coarse aggregate shall be as specified. Coarse aggregate shall be delivered to the site and stored in single sizes and combined on batching to provide a graded aggregate all in accordance with the approved mix design. Where 10mm maximum *size* aggregate is required, 10mm single-sized grading shall be used.

Fine Aggregate:

Grading of fine aggregate shall be in accordance with Grading Zone II of Table IV of IS 383 and its fineness modulus shall not be less than 2.2 nor more than 3.2 Grading as well as fineness modulus shall be monitored regularly and continuously at source as well as at Site and if necessary, sand from different approved sources shall be blended to achieve the desired grading and fineness modules.

All-in Aggregate:

All-in aggregate and crushed stone sand shall not be used for reinforced concrete and can only be used for other concrete with the approval of the Engineer.

3.3.7 Staining

Aggregates shall not be composed of or contain inclusion of materials likely to cause staining or otherwise disfigure finished concrete surfaces.

3.3.8 Washing of Aggregates

Aggregates shall be free of all silt, dust, chlorides, sulphates, organic or other impurities. If required, the aggregates shall be washed with fresh water in an efficient washing plant before delivery to Site. Tests to check the efficiency of the washing of the aggregates shall be made at regular and frequent intervals and any found to be unsatisfactory shall be rejected.

3.3.9 Sampling and Testing of Aggregates

The method of sampling shall be in accordance with IS 2430.

Tests, including grading and tests for chemical, physical and mechanical properties of the aggregate and the presence of deleterious impurities, including but not limited to silt, sulphates and chlorides, shall be carried out as required by the Engineer, in accordance with relevant parts of IS 2386 except as specifically provided otherwise in the Specification.

3.3.10 Shipping of Aggregates

Whilst being conveyed to the Site, aggregates shall be covered to prevent dust or other contamination and all necessary precautions shall be taken to prevent segregation of sizes or crushing of aggregates.

Aggregates shall be delivered to the Site at least one day before use in such consignments as shall ensure satisfactory progress of the Works.

Aggregates from separate bins or from separate stockpiles at the source of supply shall be delivered to the Site in separate vehicles. Different sizes and gradings shall not be transported in the same vehicle simultaneously.

3.3.11 Storage and Handling of Aggregates

Aggregates accepted for use in the Works shall be stored in accordance with IS 4082 in approved containers or on clean, hard, free draining paved areas draining away from the concrete mixing area, with adequate dividing walls of ample height and strength to prevent mixing of different types and sizes of aggregates. The surrounding areas where aggregates may be handled shall also be hard paved. All these areas shall not be liable to flooding. Details of the layout and sighting of the storage areas shall be submitted to the Engineer for approval before they are constructed.

Containers and storage areas shall be self-draining. Particular care shall be taken in the construction and maintenance of such containers or storage areas and in the handling of

materials to ensure that contamination by extraneous material such as air-borne dust, leaves or clay, organic and other deleterious matter or by harmful salts in the ground is prevented.

During delivery to and handling from the stockpile, care shall be taken to avoid crushing the aggregates or contamination with extraneous matter.

The general or localised build-up of fines or segregation of sizes in aggregate stockpiles shall not be allowed. If the Engineer is not satisfied that such segregation or build-up of fines has been prevented, he may instruct the Contractor to turn over the contents of any stockpile or to remove all or part of the contents of any stockpile and either reprocess or dispose of such material.

The Contractor shall also employ such methods at their own cost as may prove necessary to ensure effective cooling of the aggregates prior to batching for concrete (such as provision of sun-shades), subject to the approval and/or discretion of the Engineer. Spraying the aggregates with water will not be permitted.

3.3.12 Aggregate Test Certificates

The Contractor shall provide the Engineer with certificates from the suppliers to the effect that all aggregates comply with the requirements of this Specification, at his own cost.

3.3.13 Silt, Clay, Dust & other Deleterious Materials

The quantity of silt, clay, dust and other deleterious materials present in the aggregates for concrete at the time of use shall not exceed the limits laid down by IS 383. These shall be determined in accordance with the appropriate method given in IS 2386 (Parts I & II).

3.3.14 Site Processing of Aggregates

Due to limited availability of working areas, site processing of aggregates inside the Employer's premises will not be permitted.

3.4 Water

Water used for mixing and curing of concrete shall be free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete or steel.

Potable water shall be satisfactory for mixing and curing of concrete.

All water used for the mixing of concrete, grouts or mortar shall be clean fresh potable water. Potable water shall also be used for the curing of concrete and for the washing down of construction joints, removal of laitance, etc. It should not produce any stains or unsightly deposits on the concrete surface. The presence of tannic acid or iron compounds is objectionable. It shall have pH value of between 6.8 and 7.8. The water shall be free from

deleterious matter in solution or suspension and shall meet the requirements of IS 456, in all respects. The permissible limits are given below: -

	Material	Maximum Limit (mg./litre)	
a)	Suspended	2000	
b)	Organic	200	
c)	Inorganic	3000	
d)	Sulphates (as S03)	400	
e)	Chlorides (as Cl)	2000	for plain cement concrete
		500	for reinforced cement concrete

However, the sulphate and chloride contents of the water shall be of such a level that, taking into account the sulphate and chloride contents of the other constituent materials, the overall sulphate and chloride contents of the various constituents of concrete, grout or mortar mixes do not exceed the limits.

The Contractor shall make adequate arrangements to store sufficient water at the Site for use.

3.5 Chemical Admixtures

Accelerating, retarding, water reducing admixtures shall conform to IS 9103, integral cement water proofing admixture to IS 2645, any other admixtures to B.S. 5075 if applicable, unless otherwise specified or agreed.

All admixtures shall be supplied in containers or packages marked with the recommended dosage for each type of mix in which they are to be used.

Admixtures shall be stored strictly in accordance with manufacturers' recommendations and precautions shall be taken during delivery and storage to prevent damage to or adulteration of admixtures. This may include cleaning off sediment from the bottom of a storage tank, regular stirring, etc.

Any cement containing admixtures shall be supplied in bags or containers clearly marked to show the nature and quantity of such admixtures and shall be stored separately from any other type of cement.

Admixtures containing calcium chloride shall not be permitted in concrete containing reinforcement or other parts susceptible to degradation.

Admixtures shall be used in accordance with the manufacturer's advice.

Admixtures shall be compatible with all other mix components and shall not inhibit subsequent impregnations, coatings or other materials or processes required as part of the Works.

Any admixture used in concrete mix shall only be used at the rate of dosage or in the proportions approved by the Engineer, method of mixing etc. all in accordance with the manufacturer's instructions and within the manufacturer's recommended ambient temperature range.

In general, the dosage of retarders, plasticisers and super-plasticisers shall be restricted to 0.5, 1.0 and 2.0 per cent respectively by weight of cement unless a higher value is agreed upon between the Engineer and the Contractor based on performance tests.

Any batch of concrete which has received an incorrect dose of an admixture or which shall show deterioration after placing as a result of incorrect use of admixtures shall be broken out or otherwise replaced at no extra cost.

The relative density of liquid admixtures shall be checked for each drum containing the admixture and compared with the stated / specified value before acceptance. Liquid admixtures or powder admixtures that are to be used as solutions shall be dispensed by an appliance fixed to the mixer, which measures weight, volume or dosing time and is provided with a recorder. This appliance shall be accurately calibrated, and the calibration and dosage shall be checked at regular intervals or as directed by the Engineer. All such admixtures shall be dispensed with the mixing water.

All admixture dispensers shall be thoroughly cleaned before commencing each day's work and at every interruption to the work.

Where admixtures are to be used in bulk form, these shall be weigh-batched as is provided in this Specification for the batching of cement.

Powder admixtures to be used in dose form shall only be allowed if premixed and used as solutions and then only if the premixing procedure has been previously approved by the Engineer.

3.6 Mix Design

3.6.1 General

Concrete mix designs shall comply with the Employer's Requirements, IS 456, IS 10262, SP 23 and other applicable Indian standards and shall include:

a) Definition of environmental exposure
b) Selection of concrete type
c) Definition of reinforcement covers
d) Definition of mix design

Mix designs shall comply with the following table:

Table 3-1Concrete Requirements

Parameter	Limit
~~Reinforced concrete - Max. chloride content class~~	~~0.20~~

~~Unreinforced concrete - Max. chloride content class~~	~~0.50~~
~~Max. total estimated sulphate content (SO3) by mass of cement~~	~~3.7%~~
~~Sulphate determinations of hardened concrete~~	~~4.0%~~
Marine structures - Min. cementitious content	360~~400~~ kg/m3
Marine structures - Max. cementitious content	500 kg/m3
Marine structures – Max. water-cement ratio	0.4
Marine structures – Min. exposure class	as per IS 456

The mix shall be designed to produce the grade of concrete having the required workability and characteristic strength not less than 45 MPa as given in above table.

Alkali-silica reaction (ASR) shall be controlled in accordance with the recommendations of Building Research Establishment (BRE) Digest 330 Alkali-silica reaction in Concrete. Detailed guidance for new construction.

All reinforced concrete in the work shall be "design mix concrete" as defined in EN 206, considering the environment, concrete cover for each type of concrete and structure.

3.7 Deep Foundation Concrete

3.7.1 General

Concrete for piles shall additionally conform with DI1466-RHD-P2-MA-SP-CM-0902, Technical Specification-Part B - Piling and Deep Foundations".

3.8 Reinforcement

3.8.1 General

Unless otherwise specified, all steel reinforcement shall be Grade Fe500D high yield deformed steel bar complying with the requirements of IS 1786.

All reinforcement shall be free from loose mill scale, loose surface rust, pitting, oil, grease, paint, cement slurry and other deleterious matter that may hinder or destroy the bond.

All reinforcement used in the Works shall be clean and free of surface contaminants, which may necessitate that the reinforcement be blast-cleaned or waterjet-cleaned or otherwise cleaned before the concrete is placed.

Site bending of reinforcement (e.g. starter bars) is subject to the Engineer's review.

The use of round/smooth bar for structural reinforcement shall not be permitted.

3.8.2 Cutting and Bending

Reinforcing bars supplied bent or in coils shall be straightened cold without damage at no extra cost. No bending shall be done when ambient temperature is below 50C.

Reinforcing bars shall be accurately cut and bent to the shapes and sizes shown on the Contractor's schedules. All bars shall be bent cold unless the written permission of the Engineer is obtained for hot bending.

Stirrups and binders shall be bent to the radius of the bars against which they are to be in contact to fit closely around these bars.

Bars incorrectly bent may be used if approved by the Engineer only if the means used for straightening or re-bending have been approved by the Engineer.

3.8.3 Storage

All reinforcement shall be stored to prevent corrosion and deterioration and shall be kept clean at all times.

Fabricated and mesh reinforcement shall be carefully stored to prevent damage and distortion. Bar or rod reinforcement shall be stored in suitable racks or on dunnage on concrete slabs/ clean aggregate beds to the satisfaction of the Engineer.

3.8.4 Welding

Welding of reinforcement, including tack welding for construction purposes, shall only occur where the Contractor demonstrates to the Engineer's satisfaction that welding is required for the Works and cannot be practically achieved by other methods and that welding will not be deleterious to the capacity of the structure.

Reinforcement welding shall conform to ISO 17760. The quality and/ or strength of structural welded joints shall be assessed with tests carried out by a suitably accredited independent testing body. The results of all tests shall be submitted to the Engineer for review.

3.8.5 Reinforcement Couplers

Reinforcement couplers shall not be used unless specifically referenced on the Drawings or approved in writing by the Engineer.

Reinforcement couplers shall conform to ISO 15835.

3.8.6 Fixing of Reinforcement

The Contractor shall be responsible for maintaining the reinforcement in the correct position during concreting and compacting and to this end reinforcing bars shall be accurately fixed together as shown on the Drawings with such laps as are indicated, all to form a rigid cage. Bar crossings shall be secured tightly with two strands of annealed steel wire 0.9 to 1.6 mm thick, the ends of the wire being twisted together and bent away from the concrete surface and in no case shall encroach into the concrete cover. Every bar shall be secured in at least 2 places and in addition binding wire tying spacing shall be not greater than every fourth intersection along the bar length. Crossing bars shall not be tack-welded for assembly of reinforcement without the Engineer's permission.

Sufficient mild steel chairs shall be supplied to support rigidly the top reinforcement of all slabs. The legs of these chairs shall be kept off the bottom shutter by suitable cover blocks to provide the specified cover. PVC cover blocks deemed suitable by the Engineer shall be permitted. Spacers and /or chairs shall be placed at a maximum spacing of 1m or at closer spacing as necessary.

Substitution of reinforcement laps / splices not shown on the Drawings shall be subject to Engineer's approval. Splices / laps in adjacent bars shall be staggered.

The splicing and lapping of reinforcement bars in general shall be as per the guidelines of section 26 of IS 456.

No ferrous metal part of any device used for connecting bars or for maintaining reinforcement in the correct position shall remain within the specified minimum concrete cover to the reinforcement except where expressly instructed or provided for within the Contract.

Reinforcement shall be bent and fixed in accordance with procedure specified in IS 2502, code of practice for bending and fixing of bars for concrete reinforcement.

Unless otherwise specified by the Engineer, reinforcement shall be placed within the following tolerances:

Description	Tolerance in spacing.
For effective depth, 200 mm or less:	+/-10 mm
For effective depth, more than 200 mm:	+/-15 mm

Spacers shall be as small as practicable with sides not exceeding 50mm for their purpose and shall be securely fixed in place, by approved means, to ensure that they will not be displaced during the placing, vibration or finishing of the concrete all at the Contractor’s own cost.

Any precast spacer blocks approved for use shall be at least equal in strength to the body of the concrete in which they are being placed, with the largest size of aggregate limited to 10 mm, and the blocks cured for 14 days or more.

4 Performance Criteria

Concrete mixes shall be designed and produced to satisfy the criteria specified in the following table:

Table 4-1Performance Criteria for Concrete

Parameter	Deck Structure	Piles
28-day Compressive Strength (MPa)	45	45
Slump (mm) ± 15	150	180
Minimum Cement Content (kg/m^3)	~~360~~360	~~360~~360
Maximum Water Cement Ratio	0.4	0.4
Chloride content	Refer clause 8.1.4	Refer clause 8.1.4
Sulphate content	Refer clause 8.1.5	Refer clause 8.1.5
Alkali content	Refer clause 8.1.6	Refer clause 8.1.6

5 Contractor's Submissions

The following minimum information and documents shall be submitted to the Engineer for review at least 42 days in advance of concrete production for the Works:

a) The Contractor shall submit to the Employer at least three sets of mix design and corresponding test results after varying the mix proportions and / or grading of aggregate so as to establish the maximum density of the required grade of concrete.
b) Details of concrete mixes demonstrating compliance with the Employer's Requirements and appropriate standards, including sources, traceability and test results for the characteristics of all constituents, chloride and sulphate levels and precautions against alkali silica reaction and other degradation processes, etc.
c) Details of reinforcement and other incorporated materials to demonstrate compliance with the Employer's Requirements and appropriate standards, including sources, traceability, and test results for the characteristics of all incorporated materials
d) Method statements for the safe production, transport, placing and curing of concrete giving details of the proposed plant, equipment, methods, products and personnel
e) Sampling and testing plan for the concrete from production to the completed element
f) Inspection and test plan, including hold points for inspection
g) Report showing initial test results to demonstrate suitability of the concrete for the intended application

h) Proposed sequence of pours indicating the position and nature of joints, including details of expansion joints to demonstrate adequate movement accommodation
i) Outline contingency plans for adverse weather conditions (e.g. rain, excessive heat or cold) and for avoidance of cold joints (e.g. disruption of concrete production).
j) Method statements for making good of defects, including details of proposed materials

6 Workmanship

6.1 Construction Tolerances

Tolerances for Concrete Surfaces:

Type of Structure	Type of Irregularity	Tolerances mm			
		Type of Finish			
		Formed		Unformed	
		Class F1	Class F2	Floated	Tamped
General Exposed Concrete	Departure from alignment and grade as shown on the Drawings	+10 -10	+10 -10	+5 -5	+10 -10
	Variations in cross-sectional dimensions	+10 -5	+10 -10	NA	NA
	Abrupt	0	5	5	5
	Deviations from template in long dimensions	+5 -5	+10 -10	+10 -10	+10 -10
Exposed concrete where steelwork is to be fixed; also, tolerance for cast in steelwork	Departure from alignment and grade as shown on Drawings	+5 -5	NA NA	+3 -3	NA
	Variations in cross-sectional dimensions	+5 -3	NA	NA	NA
	Abrupt	3	NA	3	NA
	Deviation from template in long dimensions	+5 -5	NA	+3 -3	NA

(Note: NA denotes not applicable)

The tolerance in verticality for all types of finishes for walls, piers, and similar components shall be 0.05 degrees (i.e. approx. 1 in 1145).

Tolerance for concrete cover shall be in accordance with IS 456.

Holding Down Bolts

All cast-in holding bolts, ferrules, etc. shall be positioned using a template that matches the respective base plate of the element to be attached, to a minimum tolerance of +/-2 mm.

The bolts and ferrules shall be securely held in place to ensure they remain perpendicular to the concrete surface during pouring. Threads shall be protected by greasing and wrapping prior to concreting.

7 Placement

7.1 Concrete

The Contractor shall be entirely responsible for demonstrating to the Engineer that the proposed concrete complies with the Employer's Requirements e.g. mix trials, trial pours, concrete delivery notes, etc.

The ready-mix plant proposed by the Contractor for each design mix shall use truck mixers.

The time of introduction of water to the batch shall be recorded on the delivery note, together with the weight of the constituents of each batch.

The concrete shall be carried in purpose-made agitator trucks, operating continuously, or truck mixers.
Ready-mix concrete shall, where applicable, comply with the requirements of applicable Standards.

When the Contractor's submission allows and has been accepted by the Engineer, water shall be added under supervision either at the site or at the central batching plant, but in no circumstances shall water be added in transit.

The concrete mix design strength shall be specified for each delivery batch.

Materials such as cement, coarse and fine aggregates, water and admixtures, etc. shall conform to the Contract documents.

Control of the quantities of cement and other mix components shall be in accordance with applicable Standards.

The concrete shall be delivered to the site of work and discharge shall be completed within the maximum time agreed by the Engineer, determined from the mix trial and trial pour results (e.g. 60 or 90 minutes, as applicable).

Adequate facilities shall be provided by the Contractor to allow the Engineer to inspect and sample the materials used, the process of manufacture and methods of delivery of concrete.

The Contractor shall provide traceability of all materials used in the concrete to placement on site, including test results, with a system which shall be uncomplicated, open and visible to all.

The sampling and testing of concrete shall be done in accordance with the relevant requirements of applicable Standards.

The test for consistency or workability shall be carried out in accordance with the requirements of applicable Standards or by such other method as may be agreed between the Engineer and the Contractor.

Compressive strength and flexural strength tests shall be carried out in accordance with applicable Standards, and the acceptance criteria for concrete supplied on the basis of specified strength shall conform to the requirements of applicable Standards.

The Contractor shall keep batch records of the masses of all solid materials, of total mix water and of the results of all tests and forward the certificates to the Engineer within 48-hours of completing the tests.

7.1.1 Batching and Mixing

The material and proportions of concrete ingredients as established by the preliminary tests for the mix design shall be rigidly followed for all concrete works and shall not be changed, unless a revised mix and all associated testing results are submitted to the Engineer for review. Concrete shall be produced only by weigh batching the ingredients.

The mixer and weigh batcher shall be maintained in clean serviceable condition.

Concrete shall be mixed in mechanical mixers complying with IS 1791 (batch type mixers). Water shall be fed into the mixers from a tank fitted with a water measuring device and means of adjusting the flow of water. The type and manufacture of these mixers, together with all associated plant, shall be subject to the approval of the Engineer.

Where small quantities of high-grade concrete are required the Contractor shall, if the Engineer so requires, provide small, portable, covered pan mixers complying with IS 12119 of approved type for this particular work. In such case the mix shall be adjusted to whole bags of cement and no splitting of bags will be allowed.

Such covered pan mixers shall only be used as the Engineer may direct and all the conditions covering the mixing of concrete for large scale concreting shall apply to any mix prepared in pan mixers.

Mixers shall be set up on a firm level base and maintained within the manufacturer's tolerances, with particular attention to mixing blade clearances and sizes, throughout the period of the Contract and any mixer or plant that is not so maintained or is faulty in any respect shall be removed from the site.

The accuracy of the weigh batcher shall be periodically checked, at no more than 90-day intervals.

Before beginning concrete mixing operations, all hardened concrete and foreign materials shall be removed from inner surface of mixing and conveying equipment. All conveyances, buggies, barrows shall be thoroughly cleaned at frequent intervals during placing of concrete.

The maximum size of the batch shall not exceed the maximum rated capacity of the mixer as stated by the manufacturer and as stamped on the mixer and the batch size shall not be less than 75% of such maximum.

Mixing shall begin immediately after the cement has been added, either to the water or aggregate, and shall continue until there is a uniform distribution of the materials and the mass is uniform in colour and consistency or as directed by the Engineer. In any event, concrete shall be mixed for at least 2 minutes or for the period and at the drum speed specified by the manufacturer of the mixer. Concrete shall be discharged from the mixer on to a level, clean, water-free platform, or floor or into water-tight receptacles. The area surrounding the mixer shall be paved and kept clean at contractor cost. When skips or mobile concrete carriers are used, concrete may be directly discharged from the mixer into the skips or rotating drums of mobile carriers.

If there is segregation after unloading from the mixer, the concrete shall be remixed if approved by the Engineer, otherwise the mixed batch shall be rejected.

The entire contents of the mixer shall be removed from the drum before materials for a succeeding batch are placed in it. The solid materials composing a batch shall be deposited in the mixer in accordance with the manufacturer's directions for use.

Within 30 minutes after mixing of water to the cement and aggregate, or the cement to the aggregate, the concrete shall be placed in its final position in the forms and fully compacted, except that this period may be extended with the prior permission of the Engineer provided the concrete is continuously agitated in an approved purpose-built supply vehicle or an approved retarding admixture is included in the mix. If an initial set should take place, the concrete shall be rejected.

If any mixer is out of operation for more than 20 minutes, it shall be thoroughly cleaned out together with all the handling plant, before any further concrete is mixed and the first batch on recommencing shall have 10% additional cement to allow for sticking in the drum. This shall also be followed at the end of each shift of concrete mixing operation and for the first batch of concrete of the subsequent shift. All mixing and handling plant shall be thoroughly cleaned out before concrete, using a different type of cement or admixture is used.

7.1.2 Consistency and Slump

Every batch shall be tested for consistency or workability, except for zero slump concrete. The test for consistency or workability shall be completed within 15 minutes of the time of receipt of the ready-mixed concrete at site.

Every batch shall be tested for temperature within 15 minutes of the time of receipt of the ready-mixed concrete at site. Concrete shall be of a consistency and workability suitable for the conditions of the Works and the Site, and satisfying the performance criteria in section 4~~1.7~~.

7.1.3 Large Pours

Where concrete pours are greater than 1m thick in the narrowest dimension, the Contractor shall assess the proposed pour using CIRIA C766 or other approved method and shall propose measures for the Engineer's review to mitigate potential excessive concrete temperatures and temperature differentials.
When appropriate, the Contractor shall undertake a test pour of a concrete sample of dimensions to match the minimum cross-section of the proposed "large pour" and at least a metre in length. The test sample shall include thermo-couples to measure and record the concrete temperatures during hydration and temperature differentials across the sample.

7.1.4 Placement

7.1.4.1 Preparation Prior to Placement

Before concrete is placed, formwork shall be inspected by the Engineer to ensure it has been cleaned and oiled.
Temporary formwork openings shall be provided to facilitate inspection and such openings shall be later suitably plugged.
Ample time shall be permitted to install drainage and plumbing lines, floor and trench drains, conduits, hangers, anchors, inserts, sleeves, bolts frames and other miscellaneous embedment to be cast in the concrete as indicated on the Drawings or as necessary for the proper execution of the work.
All such embedment's shall be correctly positioned and securely held in the forms to prevent displacement during placement and vibration of concrete.
Slots, openings, holes, pockets etc. shall be provided in the concrete in the positions indicated in the Drawings or as required by the Contractor's Documents.
Reinforcement and other items to be cast in concrete shall have clean surfaces that shall not impair bond.
Prior to concrete placement, all works shall be inspected by the Engineer and if found unsatisfactory, concrete shall not be poured until all defects have been corrected.
Review by the Engineer of any and all Materials and work as required herein shall not relieve the Contractor from its obligation to produce finished concrete in accordance with the Drawings and the Contract.

7.1.5 Placing

Concrete shall be placed and compacted in the shortest possible time after mixing is completed and before it has taken an initial set. It shall be placed as close as possible to its final position to avoid segregation of materials and displacement of reinforcement. Freshly laid concrete shall not be wheeled over or otherwise disturbed. When depositing concrete adjacent to a construction joint, special care should be taken not to disturb the dowels or other reinforcing bars projecting from the existing concrete.

Normally concrete may be deposited with a maximum free fall of 1.5 metres without the use of pipes / chutes / elephant trunks, provided suitable measures are taken to prevent segregation and premature coating of upper reinforcing steel. When pipes are used, they shall be as far as is practicable, be kept full of concrete during placing and their lower ends shall be kept buried in the newly placed concrete. In certain circumstances greater heights than 1.5

metres may be allowed but only with the written authority of the Engineer following trials to establish the effect on the concrete.

Chutes may also be used and shall be of steel or steel lined. They shall be constantly kept clean from coatings or hardened concrete or other obstructions. Chutes shall not be set at such an angle that the concrete sticks to them or becomes segregated. Normally, chutes at an angle of more than 45 degrees to the horizontal will not be permitted.

Concreting of any section or unit of the work shall be carried out in one continuous operation between approved construction joints and no interruption of the concreting will be allowed without the approval of the Engineer. Sequence of placing shall be such as to avoid disturbance of partially set concrete.

In cases where the approval of the Engineer is obtained and where delays of more than one hour occur between successive concreting when, in the opinion of the Engineer, the previously placed concrete has had time to harden; the resulting joint shall be treated as a Construction Joint. The previously placed concrete shall be cut back to a vertical and/or horizontal face and the joint face treated.

Where open ended pipes are cast in, care shall be taken that concrete cannot enter the pipes.

Except when placing with slip forms each placement of concrete in multiple lift work, shall be allowed to set for at least 24 hours after the final set of concrete, before the start of subsequent placement. Placing shall stop when concrete reaches the top of any opening in walls or the bottom surface of slab in beam and slab construction, and it shall be resumed before concrete takes its initial set but not until it has had time to settle as determined by the Engineer.

In the event of rainstorms or other severe weather conditions arising, concreting shall be stopped, and appropriate temporary stop ends, vee grooves etc., placed as may be necessary and concrete shall be covered with tarpaulins immediately. To meet such circumstances, the Contractor shall always have in readiness approved framed sheeting, tarpaulins, etc., for the protection of newly placed concrete. Should any concrete be damaged due to rainstorms or other weather conditions, the

Engineer may order the cutting out and replacement of the damaged concrete, all at the expense of the Contractor.

Except where arrangements, approved by the Engineer are made for placing concrete under water, the areas on which concrete is to be deposited shall be made and kept free from standing water during concreting operations and running water crossing or entering such areas shall be brought under control for at least 12 hours after concreting is completed.

7.1.6 Formwork

Formwork shall be rigidly constructed and shall ensure that the finished concrete is true to the required shape, position, and level, and to the standard of finish specified. Formwork including the props (number, sizes and locations) shall be of suitable design and substantial construction to carry the loads and pressures due to the wet concrete and any incidental loads such as during concreting and compacting operations without excessive bulging, distortion, settlement,

deflection, instability and joints shall be tight enough to prevent leakage of cement slurry and fines from the concrete and which can be stripped and removed without causing any blemish or jar to the concrete. Guidelines of IS 14687 shall be followed.

Formwork for recesses, keys, chamfers and radius strips, pockets, apertures, internal voids etc. and all bolts and fittings shall be accurately positioned and securely fixed before commencement of concreting such that they are not dislodged by the concreting operation, nor hinder the striking of forms.

The shuttering for beams and slabs shall be so erected that the side shuttering of beams can be removed without disturbing the bottom shuttering of beam and slab. Formwork shall be capable of being easily removed without shock disturbance or damage to the concrete. All forms shall be constructed with removable panels or openings to permit inspection of the inside of the formwork and to allow removal of debris i.e. chippings, shavings, wires, saw dust, dust, etc. and water from the interior of the forms before the concrete is placed. If the shuttering for a column is erected for the full height of the column, one side shall be built up in section, as placing of concrete proceeds or windows left for placing concrete from the side to limit the drop of concrete to 1.5 m or as directed by the Engineer. The Contractor's attention is also drawn to the requirements of the Clauses relating to Concrete Finishes that contain some requirements for formwork construction.

Formwork shall be securely braced, wedged and firmly supported. Folding wedges, where used for final adjustments shall be nailed together and to the props, struts or buttons to prevent their loosening during vibration.

All formwork shall be fixed to the proper lines and levels and trued up immediately before depositing the concrete.

The Contractor shall take into account the structural behaviour of the concrete elements being cast and shall ensure that the formwork and staging are adequately stiff to support the concrete being placed at all stages of placing. Any eccentric loads shall be properly provided for. The Contractor shall submit the drawings and calculations for the design of the formwork to the Engineer for approval before erecting the same; however, the responsibility for the same shall be entirely of the Contractor.

Forms intended for reuse shall be treated with care. Forms that have deteriorated shall not be used. Before reuse all forms shall be thoroughly scraped, cleaned, nails removed holes suitably plugged, joints repaired, and warped lumber replaced to the satisfaction of the Engineer. Contractor shall have enough shuttering to allow for wastage so as to complete the Works in time.

Formwork showing excessive distortion, during any stage of construction shall be removed and corrected / strengthened, prior to placement of concrete.

The requirements of formwork construction for concrete placed under water are specified separately elsewhere in this Specification.

Wire ties shall not be allowed; instead bolts passing through plastic sleeves shall be used where permitted by the Engineer. The plastic sleeves shall not be nearer than 75 mm to the finished surface of the concrete. The bolt for this length of 75 mm shall be wrapped in plastic

sheet for easy removal. Holes left by the removal of bolts shall be fully grouted under pressure to the full length with 1:2 cement: sand grout and neatly plugged with same mix flush with the surface and finished to the satisfaction of the Engineer.

Permanent void formers, designed to remain in place after casting of concrete, shall be of a material approved by the Engineer.

Where use of controlled permeability formwork (CPF) liner is specified the CPF liner shall have the following properties:

- A maximum decrease in thickness of 10 % under a pressure of 200 kPa
- A maximum pore size of 0.030 mm
- A minimum water retention capacity of 0.35 litres per sqm
- A minimum tensile strength of 5 kN per m at a maximum of 5 % elongation.

The CPF liner shall have independent third-party certification and shall be submitted to the Engineer for approval. The certification shall demonstrate that the use of the CPF liner improves the performance of a CPF cast concrete against that for conventionally cast concrete. A minimum improvement of 50 % for surface tensile strength, initial surface absorption and chloride ingress is required. For liners without independent certification, tests to establish liner performance shall be performed on an appropriate concrete mix, prior to approval for use being given.

The CPF liner shall be installed and used in accordance with the manufacturer's instructions and may only be used more than once with the prior approval of the Engineer.

Except where specifically detailed on the Drawings or where further elements are to be placed against them, all exposed horizontal and vertical arises shall have a symmetrical chamfer. This chamfer shall be 25 mm x 25 mm with 45 deg angle unless detailed otherwise on the Drawings.

Before commencement of pouring concrete the faces of forms coming in contact with concrete shall be cleaned and interior of forms shall be thoroughly cleaned out of all materials mentioned in previous Clause by approved means to the satisfaction of the Engineer. Where directed, cleaning of interior of forms shall be done by blasting with a jet of compressed air at no extra cost.

A thin uniform coating of approved mould oil or other approved material shall be applied before fixing reinforcement to all surfaces coming into contact with the concrete to allow easy removal of the forms without damage to the concrete. No mould oil or other lubricating medium shall be allowed to come into contact with the reinforcement and embedded steelwork. Any material that will adhere to, discolour or impair the finish to the concrete shall not be used.

Where necessary and approved by the Engineer, to prevent absorption from the concrete, the formwork shall be thoroughly wetted shortly before concreting is commenced.

Shuttering shall be thoroughly scraped, cleaned and, if necessary, repaired before being re-used. Any part of a formwork panel which the Engineer judges incapable of producing a finish of the specified standard by reason of excessive use or the employment of sub-standard materials shall be replaced by the Contractor at his own expense.

Formwork shall not be disturbed or stripped, unless otherwise approved, until the following times have elapsed after the concrete has been poured:

Vertical formwork to beams, walls, piers, columns	24 hours
Soffit formwork to slabs, (with props left under)	3 days
Removal of props to slabs	
i) Spanning up to 4.5 m	7 days
ii) Spanning over 4.5 m	14 days
Soffit formwork to beams (with props left under)	7 days
Removal of props to beams	
i) Spanning up to 6 m	14 days
ii) Spanning over 6 m	21 days

The above time periods are however subject to approval by the Engineer depending on the strength gain characteristics determined from testing of concrete test cubes with the particular cement being used (Particularly sulphate resisting cement). It is the Contractor's responsibility to ensure that the forms are not struck until the concrete has developed sufficient strength to support itself, does not undergo excessive deformation and resists surface damage and any stresses arising during the construction period. Any damage resulting from premature removal of forms shall be made good by the Contractor at his own expense.

In case of elements with re-entrant angles, the formwork shall be removed as soon as possible after the concrete has set, to avoid shrinkage cracking occurring due to the restraint imposed.

In addition to the above, no loading (including self-weight) shall be imposed on the concrete which would cause a compressive bending stress greater than one-third of the concrete strength at the time of loading, or one-third of the 28 day strength, whichever is less.

Soffit formwork should be so designed as to facilitate striking, if required, without removal of props being necessary until the times stipulated above have elapsed.

The Contractor’s attention is drawn to the need to maintain side shutters as insulation on large concrete pours to prevent surface cracking due to thermal effects. The Contractor’s proposals for stripping shutters on pours of greater than 25m3 shall be submitted to the Engineer at least 2 weeks before the pour is due to be made.

No superimposed load shall be allowed on any part of the concrete work prior to the removal of the forms and props and/or until such loading is approved. Where concrete is to have filling placed against it the methods and materials of backfilling shall be approved by the Engineer.

Where there is a particular requirement for the early removal of formwork a procedure for establishing whether the concrete has reached the required strength shall be agreed with the Engineer beforehand. This shall be based on strength gain characteristics determined from testing of concrete test cubes.

At all times the Contractor shall delay the removal of the formwork if, in the opinion of the Engineer, the concrete contained has not attained sufficient strength.

Permissible tolerances for concrete surfaces are given in clause 6.1. If permissible tolerances are exceeded, the acceptance or otherwise of the concrete shall be decided by the Engineer. If concrete is rejected, it shall be removed and replaced by the Contractor at his own cost.

7.1.7 Casting

The sequence of construction shall be in accordance with the Contractor's Documents, the Employer's Requirements and any particular requirements for the Works as required by the design.

The Contractor shall prepare a detailed method statement for review by the Engineer.

Concrete shall be transported and placed such that contamination, segregation or loss of the constituent materials does not occur.

Concrete shall be placed in the required location/position, level, heights, etc. by pumping/ mechanically/etc.

Equipment for conveying concrete shall be of such size and design as to ensure a practically continuous flow of concrete during depositing without segregation of materials, considering the size of the job and placement location.

Concreting, once started, shall be continuous until the pour is completed.

Concrete shall be placed as rapidly as practicable to prevent the formation of cold joints or planes of weakness between successive layers or other stages within the pour.

The thickness of each layer shall be such that it can be deposited before the previous layer has stiffened.

Concrete shall not be placed in any part of the Works without allowing the Engineer to undertake the required inspections in accordance with the ITP.

7.1.8 Compaction

Conventional concrete shall be compacted during placement with approved vibrating equipment until the concrete has been consolidated to the maximum practicable density, is free of pockets of coarse aggregate and fits tightly against all formwork surfaces, reinforcement and embedded fixtures.

Particular care shall be taken to ensure that all concrete placed against the formwork faces and into corners of forms or against hardened concrete at joints is free from voids or cavities. The use of vibrators shall be consistent with the concrete mix and caution shall be exercised not to over vibrate the concrete to the point that segregation results.

After concrete has been placed it shall be thoroughly compacted by mechanical vibration applied by immersion vibrators complying with IS 2505 or, for surface finishing on thin slabs, approved surface vibrators or vibrating tampers complying with IS 2506 / IS 2514. Form vibrators if approved for use shall comply with IS 4656. Vibrators shall only be used by

competent operatives properly trained in the correct handling of the particular equipment in use on the site.

Immersion vibrators shall run at a frequency of not less than 120 Hz when immersed. The active part of the vibrator shall be fully immersed while in use and vibration shall be of sufficient duration and intensity to compact the concrete thoroughly but shall not be continued at any one point to the extent that segregation occurs. Vibrators shall not be used to transport concrete in the forms. Vibrators shall be manipulated so as to work thoroughly the concrete around the reinforcement and embedded fixtures and into the corners and angles of the forms so that all entrained air is expelled and the concrete surface when exposed is found good and free from air pockets, honeycombing or other defects. Restamping of concrete or mortar which has partially hardened shall not be permitted. Concrete once vibrated shall not be vibrated again. Impression vibrators shall be inserted vertically at points not more than 450 mm apart and withdrawn slowly till air bubbles cease to come to the surface, leaving no voids. When placing concrete in layers advancing horizontally, care shall be taken to ensure adequate vibration, blending and melding of the concrete between successive layers. Vibrators shall not be applied directly, or through the reinforcement or formwork, to sections or layers of concrete which have hardened to the degree that the concrete ceases to be plastic under vibration. Use of impression vibrators for compacting concrete shall follow the recommendations of IS 3558.

Whenever vibration has to be applied externally, the design of the formwork and the disposition of vibrators shall receive special attention to ensure efficient compaction and to avoid surface blemishes.

Every care shall be taken to see that reinforcement, and fittings attached to the shutters are not disturbed and that no damage is caused to the internal face of the shutters when using immersion type vibrators.

Over-vibration shall be avoided.

Vibration shall be supplemented by such spading as is necessary to ensure smooth surfaces and dense concrete along form surfaces and in corners and locations impossible to reach with the vibrators.

The Contractor’s attention is drawn to the importance of achieving a high degree of compaction in order to produce as dense a concrete as possible, but not over vibrating concrete against shutters thus causing an increase in the water/cement ratio local to the shutter.

When casting against existing concrete surfaces compaction should be ensured by local use of vibration to remove pockets of air that may be trapped, especially under horizontal surfaces. The requirements of this Clause do not apply in case of concrete placed under water.

7.1.9 Wet Weather

No concreting shall be carried out during periods of continuous heavy rain, unless the concrete is completely covered during mixing, transporting and placing to the satisfaction of the Engineer.

If rain should interrupt concreting, the concrete shall be adequately protected.

7.1.10 Hot Weather

In the event that the temperature during the pour is forecast to exceed 350C, the Contractor shall assess the proposed pour using an approved method and shall propose mitigating measures for the Engineer's review.

Mitigating measures may include but are not limited to:

a) Shading and/or watering of aggregates

b) Chilled mix water

c) Ice replacement of mix water

Concreting shall not be carried out if the temperature of the concrete mix at the point of placement exceeds 32ºC.

In order to lower mix temperatures, concrete may be mixed and placed at night, provided the lighting and other arrangements are to the Engineer's satisfaction.

7.1.11 Curing

All concrete shall be cured by keeping it continuously damp for the period of time required for complete hydration and hardening to take place.

Curing shall be started after 8 hours of placement of concrete, and in hot weather after 4 hours. Preference shall be given to the use of continuous sprays or by ponding of water, continuously saturated coverings of sacking, canvas, hessian (especially on vertical structural members) or other absorbent materials or approved effective curing compounds applied with spraying equipment capable of producing a smooth even textured coat.

Extra precautions shall be exercised in curing concrete during hot weather as outlined herein. Certain types of finishes or preparation for overlaying concrete must be undertaken at certain stages of the curing process and special treatments may be required for specific concrete surface finishes.

Fresh concrete shall be kept continuously wet for a minimum period of 10 days from the date of placing of concrete.

Curing of exposed surfaces shall begin immediately after the concrete has hardened. Water shall be applied to unformed concrete surfaces within one hour of final set. Water shall be applied to formed surface immediately upon removal of forms. Water flows shall be controlled

so as to prevent erosion of freshly placed concrete. The quality of curing water shall be the same as that used for mixing concrete.

Curing shall be assured by use of an ample water supply under pressure in pipes with all necessary appliances of hose, sprinklers and/or spraying devices producing a continuous fine moist spray or sprinkling.

For curing of concrete in pavements, side-walks, floors flat roofs or other level surfaces, the ponding method of curing is preferred.
Special attention shall be given to edges and corners of the slab to ensure proper protection to these areas.

Ponded areas shall be kept continuously filled with water during the curing period.

All equipment and materials required for curing shall be ready for use before concrete is placed.

Curing of concrete surfaces may be carried out by sealing with opaque, reflective plastic sheeting held in close contact with the surface of the concrete and forming an airtight fit around the element being cured.

The sheeting shall form a continuous seal and be without tears or holes. If necessary, the Contractor shall provide frames for the plastic sheeting so that the covers can be placed over deck slab pours immediately after the concrete has been floated off and before the brush finish is applied. Such frames can be removed as soon as the concrete is strong enough to support the plastic sheeting without leaving an impression in the concrete surface.

7.1.12 Protection

Immediately after compacting and finishing, and thereafter until the concrete has achieved the strength specified, the concrete shall be protected from harmful weather effects including rain, sun, wind, rapid temperature changes and from drying out.

The concrete shall also be protected from other work in progress.

No equipment, vehicles, workman or materials shall traverse recently placed concrete until the concrete is sufficiently strong and will not be damaged. Indicative times and required concrete strengths shall be tabulated below.

Table 7-1:Use of Recently Poured Concrete

Use	Age	Required Strength
Pedestrian traffic	3 days	15 MPa or 50% Design Strength
Storage of Materials	7 days	75% Design Strength
Vibration within 10m	14 days	80% Design Strength
Vehicles & Equipment	28 days	100% Design Strength

(if so designed)		

7.1.13 Finishing

This section details the treatment of concrete surface for all structures.
Concrete deck surfaces (including pedestrian-only areas) shall be stiff broom finished with a nylon broom to produce regular corrugations. Broom strokes shall be transverse to the direction of the fall on the slabs.
Upon removal of forms, all fins and other projections on the surfaces shall be carefully removed, offsets levelled voids and/or damaged sections immediately saturated with water and repaired by filling with concrete or mortar of the same composition as was used in the concrete.

All formed finished surfaces shall present a uniform and smooth appearance.

All concrete shall be protected against damage until fully cured.

The qualities of finishes required shall be as defined in Table F.4 of EN 13670 Execution of concrete structures.

7.1.14 Bonding Mortar

Concrete construction joints shall be covered with an approved bonding cement slurry immediately before concrete placement.
Grout where used shall be non-shrink grout with minimum 28 days compressive strength of 45N/mm2.

7.1.15 Grouting

The base plates of all the Steel Structures shall be grouted to thickness as shown on the relevant structural drawings, after the alignment and approval of the Engineer.

The grout shall consist of:

a) 1:2 (1 cement: 2 sand) mortar for operating platforms (not supporting Equipment), pipe supports up to 2.5 metres in height (above concrete top), cross-over, staircases, ladders, lightweight steelwork. Or:
b) Free flow non shrink Grout (Pre-mix type/CONBEXTRA GP2 of M/s Fosroc Chemicals or equivalent approved by Engineer) of compressive strength not less than 60N/mm^2, for all structures other than those covered in (i) above, as per the instructions/recommendations of the manufacturer.

Crushing strength of the grout shall generally be one grade higher than the base concrete. Minimum grade of grout shall be M35 for equipment foundations and M 40 for dynamic equipment foundations.

Nominal thickness of grouting shall be at least 50 mm for conveyor trestle base plates, building columns and pedestals of major equipment or as specified by the equipment supplier.

Surfaces to be grouted shall be thoroughly roughened and cleaned of all foreign matter and laitance.

Anchor bolts, anchor bolt holes and the bottom of equipment and column base plates shall be cleaned of all oil, grease, dirt and loose material. The use of hot, strong caustic solution for this purpose will be permitted. Prior to grouting, the hardened concrete surfaces to be grouted shall be saturated with water. Water in anchor bolt holes shall be removed before grouting is started.

Forms around base plates shall be reasonably tight to prevent leakage of the grout. Adequate clearance shall be provided between forms and base plate to permit grout to be worked properly into place.

Grouting, once started, shall be done quickly and continuously to prevent segregation, bleeding and breakdown of initial set. Grout shall be worked from one side of one end to the other to prevent entrapment of air. To distribute the grout and to ensure more complete contact between base plate and foundation and to help release entrapped air link chains can be used to work the grout into place.

Grouting through holes in base plates shall be by pressure grouting.

7.1.16 Joints

Construction Joints

- Stoppages in concreting at the end of a period of work shall be made at properly formed construction joints in positions of low shear stress.
- Where shown on the Drawings, recesses shall be formed in construction joints in order to form a key with adjacent concrete.
- Formwork to provide stop ends for vertical joints in reinforced concrete shall be firmly fixed and cut around the reinforcement.
- Concrete which passes through the stop ends shall, after setting, be removed.
- Retarding agents shall not be used on stop end forms.

The surface of construction joints shall, when the concrete has set but not hardened, be prepared by removing the outer mortar skin using a stiff brush and a fine spray of water, to the extent that the large pieces of coarse aggregate are exposed but not damaged or dislodged. Alternatively, expanded metal mesh may be used to form a roughened surface, provided that the mesh is removed with care within 24 hours of casting.

If this procedure is not possible, the laitance shall be removed with a combined jet of air and water. If the concrete is too hard, sand blasting, wire brushing or scabbling may be used with care. The prepared joint surface shall be cured using only fresh water.

The joint surface shall be thoroughly cleaned with compressed air or other equally efficient methods and then jetted with clean water shortly before the adjacent concrete pour is placed. Special care shall be taken to butt the new concrete thoroughly against the old.

Following the construction joint preparation and application of the bonding cement slurry, further concreting beyond the construction joint shall conform with the approved method statement including for formwork, reinforcement placement, concrete cover to reinforcement, concrete mix properties including slump, concrete placement and compaction and subsequent curing of the new concrete.

7.1.17 Breaking Out Concrete

The extent of concrete removal on repair works to existing structures shall be in accordance with the Drawings.
Broken out concrete surfaces and exposed reinforcement shall be protected from salt water splash and spray, where applicable.

The period between breaking out existing concrete and placing new repair concrete shall be minimised and in no cases longer than 7 days.

The Contractor's method of breaking out shall be designed to minimize damage to existing concrete and reinforcement e.g. hydro demolition is preferred to breakers.

The Contractor shall submit details of his proposed method equipment and staff to be used for review prior to commencing work.

Concrete surfaces that have been cut-back shall be prepared by grit-blasting or scabbling and chipping out loose projecting coarse aggregate to expose a sound matrix of rough profile.

Marine and other growth and other detritus shall be removed by high pressure water jetting or similar means to expose the concrete face and the Contractor shall ensure that all oil or grease is removed by cleaning, in conjunction with suitable detergent if required.

The substrate shall be soaked with fresh water for a period not less than 8 hours prior to concreting such that the bonding surface is in a saturated surface dry condition at the time of placing the repair concrete.

Bonding agents shall not be employed.

8 Testing And Inspections

8.1 Quality Parameters

8.1.1 Characteristic Strength

The specified characteristic strength of a designed mix shall be the 28-day compressive cube strength (N/mm2) equal to or greater than the value in the performance criteria in section 4~~1.7~~.

8.1.2 Mix Reference

The mix reference of concrete shall define its grade, nominal maximum size of aggregate, type of cement, type of aggregate, minimum cement content, maximum water/cement ratio and rate of sampling for strength testing.

8.1.3 Water/ Cement Ratio

The water/cement ratio of the concrete mix shall be the minimum value required to give adequate workability of the concrete but shall not exceed the maximum value stated in the performance criteria in section 4, which is a free water/cement ratio.

8.1.4 Chloride Content of Concrete

The total chloride content of the concrete mix, expressed as a percentage of chloride ion by mass of cement, shall not exceed 0.1% for concrete made with cement according to applicable Standards.

The chloride content shall be measured in accordance with applicable Standards.

8.1.5 Sulphate Content of Concrete

The total sulphate content of the concrete mix by mass of sulphur trioxide by mass of cement shall not exceed 4.0%.

8.1.6 Alkali Content of Concrete

The total acid soluble alkali content of the mix, expressed as equivalent sodium oxide, shall not exceed 3 kg/m3 when measured as described in the British Cement Association document “Minimizing the risk of alkali aggregate reaction”.

8.2 Sampling and Testing of Aggregates

Samples of the mix design aggregates, and determination of suitability shall be taken in the presence of the Engineer and delivered to the laboratory, well in advance of the scheduled placing of concrete.

Records of tests, which have been made on proposed aggregates and on concrete made from this source of aggregates, shall be furnished to the Engineer in advance of the work for use in determining the aggregate suitability.

From time to time or at time interval required by the Engineer, at least 5% of all samples shall be independently verified.

8.3 Testing

Each Production Sample shall be tested in the following respect: -

- Proportion of natural (uncrushed) material (% by weight)
- Gradings; deleterious materials including clay, silt and fine dust and organic impurities (% by weight), IS 2386 (Parts I & II)
- Specific gravity and water absorption, IS 2386 (Part III)
- Flakiness and elongation indices, IS 2386 (Part I)

Representative portions of equal weight shall be taken from each of the nine Production Samples of each size of aggregate, and then combined to provide Composite Production Samples for each size of aggregate. The Composite Samples shall be tested in the same respects as the individual Production Samples and shall also be tested, unless otherwise directed by the Engineer. Stockpile samples shall be compared with production samples and if differences are observed the Engineer will require appropriate tests to be carried out on the Stockpile samples.

The Engineer, if required, shall direct the Contractor to test composite samples for the following:

- Chloride content (as per DIN 4226 Part 3, Clause 3.6.5), sulphate content (as per DIN 4226 Part 3, Clause 3.6.4)
- Alkali Aggregate Reactivity tests. IS 2386 (Part VII)
- Soundness test: IS 2386 (Part V)
- Aggregate Crushing Value, IS 2386 (Part IV)
- Test fraction in oven-dry condition
- Test fraction in saturated surface-dry condition
- Aggregate Abrasion Value, IS 2386 (Part IV)
- Petrographic examination and description, including approximate composition, IS 2386 (Part VIII)

8.4 Sampling and Testing of Water

Water drawn from municipal water that is certified potable shall not require sampling or testing.

Sampling and testing of other water used for concrete batching and curing shall conform with EN 1008.

8.5 Sampling and Testing of Reinforcement

8.5.1 Test Certificates

The Contractor shall supply to the Engineer the manufacturer's test certificate for each reinforcement consignment delivered to Site, together with a delivery note stating the weight, number, length, dimension, and place of origin of the bars or fabric in each consignment.

Tests to the applicable standards shall be carried out and test certificates provided to the Engineer, as a minimum (where applicable), for:

(a) Tensile strength
(b) Proof stress
(c) Elongation percentage
(d) Bend
(e) Chemical composition
(f) Weld tensile
(g) Weld ductility

8.5.2 Reinforcement Samples for Independent Testing

The Contractor shall, in the presence of the Engineer, cut samples from any reinforcing bars or fabric whenever the Engineer directs.

Minimum sample length shall be 600mm or 20 times the bar diameter, whichever is greater.

8.5.3 Testing

The required properties of reinforcing steels shall conform with IS 1786 unless otherwise stated in the Employer’s Requirements or applicable Standards.

8.6 Trial Mixes

8.6.1 General

The Contractor shall prepare a number of trial mixes using the approved aggregates and cement and, where applicable, approved admixtures.

The Contractor shall make, cure and test specimens for strength and for all other tests as required by the Employer’s Requirements.

Specimens shall be cubes for each class of concrete in accordance with applicable Standards, cured in water at the ambient air temperature.

The Contractor shall give notice in writing to the Engineer to enable the Engineer to be represented at the making of the trial mixes and compressive testing of the cubes.

8.6.2 Mixing

Trial mixes shall be made at temperatures similar to those likely to occur during construction and preferably using the batching plant and transport to be employed in the Works.

The trial mixes shall be transported a representative distance before making the test cubes.

8.6.3 Samples

Nine test cubes shall be taken from three separate batches for each concrete mix design.

From each set of nine cubes, three shall be tested at 7 days and three at 28 days.

The three remaining cubes shall be tested at either 3 days or 56 days to assess the short term or long-term compressive strengths, as appropriate for the intended mix's purpose.

8.6.4 Mix Design

The Contractor shall submit to the Engineer for review full details of trial mixes proposed for the Works, including:

- Grading of the coarse and fine aggregates.
- Ratio by weight of all constituents of the mix;
- Compacting factor and slump test results;
- Test cube/ cylinder results;
- Water penetration test.

No concrete shall be used in the Works until the test cubes have attained the required strength at the age specified.

8.6.5 Calculations

The Contractor shall supply to the Engineer copies of all calculations relevant to the determination of the proportions of each class of mix.

8.7 Sampling and Testing of Concrete

8.7.1 General

Concrete samples shall be tested either at an on-site certified laboratory or an independent certified laboratory.

All arrangements to sample, transport, cure and store concrete samples shall be at the Contractor's cost, except when the Engineer elects to independently test.

Samples from fresh concrete shall be taken as per applicable Standards and cubes shall be made, cured and tested at 28 days in accordance with applicable Standards.

For preliminary indications of the quality of concrete, an optional test on beams for modulus of rupture at 3 days or at 7 days or for compressive strength tests at 3 days or at 7 days may be carried out, in addition to 28 days compressive strength tests.

In all cases, the 28 days compressive strength specified shall solely be the criterion for acceptance or rejection of the concrete.

The Engineer may relax the frequency of 28 days compressive strength testing, provided expected strength values at the specified early age are consistently met.

A random sampling procedure shall be adopted to ensure that each concrete batch shall have a reasonable chance of being tested, i.e. the sampling shall be spread over the entire period of concreting and cover all mixing units.

The minimum frequency of sampling of concrete of each grade shall be in accordance with the table below:

Table 8-1Sample Frequency

Concrete Quantity (m^3)	Minimum Number of Samples
<5	1
5-15	2
16-30	3
	4
>50	4 + 1 sample/ additional 50 m^3

At least one sample shall be taken from each shift.

Three test specimens shall be made from each sample for testing at 28 days.

Additional cubes may be required for various purposes such as:

- to determine the strength of concrete at 3 and/or 7 days, or
- at the time of striking the formwork, or
- to determine the duration of curing, or

- to check the testing error.

Additional cubes may also be required for testing cubes cured by accelerated methods as described in applicable Standards.

The specimen shall be tested as described in applicable Standards.

The test strength of the samples shall be the average of the strength of three specimens.

The individual variation shall not be more than (+/-) 15 percent of the average.

Slump and temperature tests shall be carried out for every batch prior to placement.

Slump and temperature testing shall be done immediately after sampling and also at the workface before the concrete is placed.

The results of all tests carried out to control the quality of concrete and concrete materials shall be recorded by the Contractor on suitable forms provided by him which shall be subject to review by the Engineer.

8.7.2 Acceptance Criteria

The concrete shall be deemed to comply with the strength requirement if:

- The mean strength determined from any group of four consecutive test results complies with the appropriate limits in Column 2 of figure below.
- *Any individual test result complies with the appropriate limits in Column 3 of* the table below.

Figure 8-1Acceptance Criteria for Concrete Structures

Specified Grade	Mean of the Group of 4 Non-overlapping consecutive test results in N/mm^2	Individual Test Results in N/mm^2
(1)	(2)	(3)
M 15	$\geq f_{ck}$ + 0.825 x established standard deviation (rounded off to nearest 0.5 N/mm^2) or, • f_{ck} + 3 N/ mm^2, whichever is greater	$\geq f_{ck}$ – 3 N/mm^2
M 20 or above	• $\geq f_{ck}$ + 0.825 x established standard deviation (rounded off to nearest 0.5 N/mm^2) or, • f_{ck} + 4 N/ mm^2, whichever is greater	$\geq f_{ck}$ – 4 N/mm^2

If the concrete is deemed not to comply based on the above figure, the structural adequacy of the part affected shall be investigated and any consequential action needed shall be taken.

Concrete of each grade shall be assessed separately.

Concrete shall be assessed daily for compliance.

Concrete for pavements shall include flexural strength tests to ensure the design assumptions used in calculations.

The number of tests shall be approved by the Engineer (not less than 2 test every 1,000 m2).

Concrete of each grade may be rejected if:

(a) It is porous or honeycombed,

(b) Its placing has been interrupted without providing a proper construction joint,

(c) The reinforcement has been displaced beyond the tolerances specified, or

(d) Construction tolerances have not been met.

Hardened concrete may be accepted after carrying out remedial measures to the satisfaction of the Engineer.

8.8 Tests on Completion

Immediately after stripping formwork, all concrete shall be carefully inspected and any defective work or small defects either removed or made good.

In case of any doubt regarding the grade of concrete used, either due to poor workmanship or based on cube/cylinder strength test results, the Contractor may be required to carry out compressive strength tests of concrete cores, ultrasonic test and/or load or other test as instructed by the Engineer.

In case ultrasonic testing does not satisfy the requirement above, the Engineer shall be at liberty to reject the concrete and to decide if the Contractor shall dismantle and redo the same or to carry out remedial measures as accepted by the Engineer at the Contractor's cost.

If the Engineer requires any independent testing of the concrete, the Contractor shall arrange for transportation of the cubes/ cylinders to a laboratory nominated by the Engineer.

In the event that cube/ cylinder tests give unsatisfactory results the Contractor shall also conduct tests agreed with the Engineer as being conclusive (e.g. core test) to prove the suitability of concrete.

The cost of the conclusive tests shall be borne by the Contractor.

If the results of any test prove unsatisfactory or the structure shows signs of weakness, undue deflection or faulty construction the Contractor shall remove and rebuild the member(s) involved or carry out such other remedial measures as may be required by the Engineer.

The Contractor shall bear all costs of remedial works.

9 Deliverables

9.1 Pre-construction Documentation

The Contractor shall, during the pre-construction phase of the works, submit to the Engineer:

(a) Proposed materials and associated test results

(b) Proposed suppliers/ manufacturers and associated certification

(c) Mix trial test results

(d) Preliminary method statements (RAMS)

(e) Inspection and test plan (ITP)

Fabrication and construction shall not commence until the Engineer has reviewed the above document.

9.2 Delivery to Site

The Contractor shall, on delivery of materials to the Site, submit to the Engineer the manufacturer's/suppliers associated documentation, with certified test results.

Materials such as bundles of reinforcement, admixtures, etc. shall be clearly labelled to enable traceability.

9.3 Inspection of Concrete Surfaces

No concrete surface shall be worked on in any way after the removal of formwork, or permanently covered up, until it has been inspected by the Engineer.

9.4 Records

The Contractor shall submit to the Engineer manufacturer's/supplier's certifications and test results for all concrete components, reinforcement, fittings, etc.

Detailed records shall be kept by the Contractor of all batches of concrete, of their mix reference, date and time of manufacture, position in the Works and of all associated tests and measurements.

Records shall also include actual casting sequence and actual mix constituent quantities.

Mix and ambient temperatures and wind speed shall be recorded.

Copies of all records shall be supplied to the Engineer, within 24 hours of the recorded event.

10 Defective concrete

Concrete, which is defective from any cause whatsoever shall, if so directed by the Engineer, be cut out and the work reconstructed at the Contractor's expense.

Defective concrete may include, but shall not be limited to:

(a) 28-day compressive and/or tensile strength less than design requirements.

(b) Finished surface or face of concrete out of dimensional tolerance.

(c) Finished surface or face of concrete out of positional tolerance.

(d) Surface texture does not meet the Employer's Requirements.

(e) Inconsistent and variable colour of exposed concrete.

(f) Concrete mix components do not meet the specification.