Project Employer's Requirements IN-PPV-0433

APMT PER#002
MATERIALS

PART A
CONCRETE AND REINFORCEMENT

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02A.1 INTRODUCTION

02A.1.1 Purpose and Scope

02A.1.1.1 This document defines the requirements for the design, supply and construction of concrete and steel reinforcement for use in the Works.

02A.1.2 General

02A.1.2.1 All Materials used in the Works shall be new unless approved otherwise by the Engineer.

02A.1.2.2 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.

02A.1.2.3 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.

02A.1.2.4 In case of any conflict between the relevant codes and standards and the Employer's Requirements, the most onerous criteria shall apply.

02A.1.2.5 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.

02A.1.3 Hazardous Materials

02A.1.3.1 The use of hazardous materials shall be avoided wherever possible, and minimised to the maximum possible extents.

02A.1.3.2 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*").

02A.1.4 Applicable Codes

02A.1.4.1 This PER 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:

a) IS 456: Plain and reinforced concrete – Code of practice

b) IS 13920: Ductile detailing of reinforced concrete structures subjected to seismic forces – Code of practice

c) IS 12269: Ordinary Portland Cement, 53 Grade – Specification

d) IS 3812: Pulverized fuel ash – Specification

e) IS 12089: Specification for granulated slag for the manufacture of Portland slag cement

f) IS 383: Specification for coarse and fine aggregates from natural sources for concrete

g) IS 1903: Concrete admixtures – Specification

h) IS 1199: Methods of sampling and analysis of concrete

i) IS 516: Methods of tests for strength of concrete

j) SP 23: Handbook on concrete mixes (Bureau of Indian Standards)

k) IS 4925: Concrete batching and mixing plant – Specification

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l) IS 1786: High strength deformed steel bars and wires for concrete reinforcement – Specification

m) IS 2502: Code of practice for bending and fixing of bars for concrete reinforcement

n) IS 14687: Falsework for concrete structures – Guidelines

o) EN 197-1: Cement: Composition, specification and conformity criteria for common cements

p) 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.

q) EN 12350: Testing fresh concrete

r) EN 12390: Testing hardened concrete

s) EN 12620: Aggregates for concrete

t) EN 13670: Execution of concrete structures

u) EN 13791: Testing concrete

v) BS 6349: Maritime works

02A.2 SCOPE OF WORKS

02A.2.1.1 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.

02A.2.1.2 This document does not consider repairs to degraded reinforced concrete structures.

02A.2.1.3 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.

02A.3 MATERIAL SPECIFICATION

02A.3.1 Concrete - General

02A.3.1.1 Components

02A.3.1.1.1 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.

02A.3.1.1.2 All concrete mix designs and material components shall be subject to review by the Engineer.

02A.3.1.2 Conformity

02A.3.1.2.1 The Contractor shall submit to the Engineer certificates attesting to the conformity of all Materials to all applicable standards.

02A.3.1.2.2 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.

02A.3.1.3 Environment

02A.3.1.3.1 To provide robust and site-specific concrete structures, the Contractor shall ensure the following issues are addressed in the Works:

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a) Environmental conditions e.g. exposure to chlorides, abrasion, etc.

b) Available materials e.g. aggregate characteristics, cementitious replacement materials, reinforcement sizes, etc.

c) Suitability of the selected construction methodology e.g. concrete pump vs. crane, underwater concrete placement, reinforcement laps vs. couplers vs. welding, etc.

d) Anticipated maintenance regime and design life of the structure

e) Health and safety for the Contractor's Personnel, Employer's Personnel and other contractors

02A.3.1.3.2 The Contractor shall ensure the concrete mix design(s) and construction methods are suitable to restrict concrete degradation mechanisms including but not limited to:

a) Chloride permeation

b) Carbonation

c) Sulphate attack

d) Abrasion

e) Delayed ettringite formation

02A.3.1.3.3 The use of coatings and/ or impregnations for concrete repairs is acceptable, subject to the Engineer's review.

02A.3.1.3.4 Coatings/ impregnations may be employed as a supplement to, but shall not be a substitute for, appropriate designs, materials, etc. for new construction.

02A.3.1.3.5 Stainless steel reinforcement shall not be used.

02A.3.1.3.6 Epoxy-coated or galvanized reinforcement shall not be used.

02A.3.2 Cement

02A.3.2.1 Types

02A.3.2.1.1 Cement shall conform to EN 197 and comply with:

a) CEM I (PC)

b) CEM I with mineral admixtures to conform to the following cement types:

(i) CEM IIB-V (cement-fly ash)

(ii) CEM IIIA (cement-GGBS)

(iii) CEM IIIB (cement-GGBS)

02A.3.2.1.2 All cement and mineral admixtures shall comply with the relevant standards, including but not limited to:

a) Ordinary Portland Cement shall be Grade 53 and comply with IS 12269

b) Fly ash shall conform to Grade 1 of IS 3812

c) GGBS shall conform to IS 12089

02A.3.2.1.3 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.

02A.3.2.2 Storage

02A.3.2.2.1 Bulk cement shall be stored in bins or silos that provide complete protection from dampness, contamination and minimize cracking and false set.

02A.3.2.2.2 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

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insulated from the floor to avoid contact with moisture from ground and so arranged as to provide ready access.

02A.3.2.2.3 Where excessive concrete temperatures may occur, cement shall be stored in such a manner as to minimise temperature increases from solar radiation (solar gain).

02A.3.2.2.4 Damaged cement bags shall not be used and shall be removed from Site.

02A.3.2.2.5 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.

02A.3.2.2.6 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.

02A.3.3 Aggregate

02A.3.3.1 General

02A.3.3.1.1 All aggregate shall conform to IS 383.

02A.3.3.1.2 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

02A.3.3.1.3 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.

02A.3.3.1.4 Aggregates shall consist of natural sand, crushed stone and gravel from sources known to produce satisfactory aggregate for concrete.

02A.3.3.1.5 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.

02A.3.3.1.6 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.

02A.3.3.1.7 Aggregate with less than 2.6 specific gravity (saturated surface dry) shall not be used.

02A.3.3.1.8 Reclaimed aggregate shall not be used.

02A.3.3.1.9 Sea-dredged aggregate shall not be used.

02A.3.3.2 Fine Aggregate

02A.3.3.2.1 Fine aggregate, for other than lightweight concrete, shall consist of natural sand and/or crushed stone sand conforming to the applicable Standards.

02A.3.3.2.2 Crushed sand shall be acceptable provided the constituent rock/ gravel composition is sound, hard, dense, non-organic, uncoated and durable against weathering.

02A.3.3.2.3 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.

02A.3.3.2.4 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.

02A.3.3.3 Coarse Aggregate

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02A.3.3.3.1 Coarse aggregate shall consist of natural or crushed stone and gravel conforming to the applicable Standards.

02A.3.3.3.2 Coarse aggregate shall be angular in shape and have predominately granular or crystalline (fracture) surfaces.

02A.3.3.3.3 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.

02A.3.3.3.4 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.

02A.3.3.3.5 Coarse aggregates shall be well graded and shall conform to IS 383 limits.

02A.3.3.3.6 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.

02A.3.3.3.7 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.

02A.3.3.4 Aggregate Storage

02A.3.3.4.1 All aggregates shall be stockpiled separately on Site or within properly constructed bins to avoid intermixing of different aggregates.

02A.3.3.4.2 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.

02A.3.3.4.3 Segregation of aggregates shall be prevented and segregated aggregates shall not be used.

02A.3.3.4.4 Rejected segregated aggregates may be used after remixing, provided that test results show compliance with the required gradation.

02A.3.3.4.5 Where excessive concrete temperatures may occur, aggregates shall be stored in such a manner as to minimise temperature increases from solar radiation (solar gain).

02A.3.3.4.6 Stored aggregates may be watered to stabilise moisture content and temperature.

02A.3.4 Water

02A.3.4.1 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.

02A.3.4.2 Potable water shall be satisfactory for mixing and curing of concrete.

02A.3.4.3 Water conforming with IS 456 and EN 1008 shall be used for mixing of concrete. Seawater shall not be used.

02A.3.5 Chemical Admixtures

02A.3.5.1 Chemical admixtures shall conform to EN 934 and IS 1903.

02A.3.5.2 Admixtures containing calcium chloride shall not be permitted in concrete containing reinforcement or other parts susceptible to degradation.

02A.3.5.3 Admixtures shall be used in accordance with the manufacturer's advice.

02A.3.5.4 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.

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02A.3.6 Mix Design

02A.3.6.1 Concrete mix designs shall comply with the Employer's Requirements, IS 456, BS 6349 and other applicable standards.

02A.3.6.2 The Contractor shall select the proportions of the mix to satisfy the strength and other requirements detailed in the Employer's Requirements as well as applicable Standards.

02A.3.6.3 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.

02A.3.7 Deep Foundation Concrete

02A.3.7.1 Concrete for piles shall additionally conform with PER #002 Part J: "*Piling and Deep Foundations*".

02A.3.8 Reinforcement

02A.3.8.1 General

02A.3.8.1.1 Unless otherwise specified, all steel reinforcement shall be Grade Fe500D high yield deformed steel bar complying with the requirements of IS 1786.

02A.3.8.1.2 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.

02A.3.8.1.3 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.

02A.3.8.1.4 Site bending of reinforcement (e.g. starter bars) is subject to the Engineer's review.

02A.3.8.1.5 The use of round/smooth bar for structural reinforcement shall not be permitted.

02A.3.8.2 Storage

02A.3.8.2.1 All reinforcement shall be stored to prevent corrosion and deterioration and shall be kept clean at all times.

02A.3.8.2.2 Fabricated and mesh reinforcement shall be carefully stored to prevent damage and distortion.

02A.3.8.2.3 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.

02A.3.8.3 Welding

02A.3.8.3.1 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.

02A.3.8.3.2 Reinforcement welding shall conform to ISO 17760.

02A.3.8.3.3 The quality and/ or strength of structural welded joints shall be assessed with tests carried out by a suitably accredited independent testing body.

02A.3.8.3.4 The results of all tests shall be submitted to the Engineer for review.

02A.3.8.4 Reinforcement Couplers

02A.3.8.4.1 Reinforcement couplers shall not be used unless specifically referenced on the Drawings or approved in writing by the Engineer.

02A.3.8.4.2 Reinforcement couplers shall conform to ISO 15835.

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02A.4 PERFORMANCE CRITERIA

02A.4.1.1 Concrete mixes shall be designed and produced to satisfy the criteria specified in the following table:

Table 02A.1 - Performance 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
Maximum Cement Content (kg/m^3)	500	500
Maximum Water Cement Ratio	0.4	0.4
Chloride content	Refer clause 02A.8.1.4	Refer clause 02A.8.1.4
Sulphate content	Refer clause 02A.8.1.5	Refer clause 02A.8.1.5
Alkali content	Refer clause 02A.8.1.6	Refer clause 02A.8.1.6

02A.5 CONTRACTOR'S SUBMISSIONS

02A.5.1.1 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: Hold Point

a) 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.

b) 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

c) Method statements for the safe production, transport, placing and curing of concrete giving details of the proposed plant, equipment, methods, products and personnel

d) Sampling and testing plan for the concrete from production to the completed element

e) Inspection and test plan, including hold points for inspection

f) Report showing initial test results to demonstrate suitability of the concrete for the intended application

g) Proposed sequence of pours indicating the position and nature of joints, including details of expansion joints to demonstrate adequate movement accommodation

h) 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)

i) Method statements for making good of defects, including details of proposed materials

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02A.6 WORKMANSHIP

02A.6.1 Construction Tolerances

02A.6.1.1 Unless defined otherwise in the Contract, construction tolerances shall conform to EN 13670. Inspection Point

02A.6.1.2 Tolerance for concrete cover shall be in accordance with IS 456.

02A.6.2 Holding Down Bolts

02A.6.2.1 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. Inspection Point

02A.6.2.2 The bolts and ferrules shall be securely held in place to ensure they remain perpendicular to the concrete surface during pouring. Inspection Point

02A.6.2.3 Threads shall be protected by greasing and wrapping prior to concreting. Inspection Point

02A.7 PLACEMENT

02A.7.1 Concrete

02A.7.1.1 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. Inspection Point

02A.7.1.2 The ready-mix plant proposed by the Contractor for each design mix shall use truck mixers.

02A.7.1.3 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. Inspection Point

02A.7.1.4 The concrete shall be carried in purpose-made agitator trucks, operating continuously, or truck mixers.

02A.7.1.5 Ready-mix concrete shall, where applicable, comply with the requirements of applicable Standards.

02A.7.1.6 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.

02A.7.1.7 The concrete mix design strength shall be specified for each delivery batch. Inspection Point

02A.7.1.8 Materials such as cement, coarse and fine aggregates, water and admixtures, etc. shall conform to the Contract documents. Inspection Point

02A.7.1.9 Control of the quantities of cement and other mix components shall be in accordance with applicable Standards. Inspection Point

02A.7.1.10 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). Inspection Point

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02A.7.1.11 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.

02A.7.1.12 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.

02A.7.1.13 The sampling and testing of concrete shall be done in accordance with the relevant requirements of applicable Standards.

02A.7.1.14 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.

02A.7.1.15 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.

02A.7.1.16 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.

02A.7.2 Batching and Mixing

02A.7.2.1 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. Review Point

02A.7.2.2 Concrete shall be produced only by weigh batching the ingredients.

02A.7.2.3 The mixer and weigh batcher shall be maintained in clean serviceable condition.

02A.7.2.4 The accuracy of the weigh batcher shall be periodically checked, at no more than 90-day intervals. Review Point

02A.7.3 Consistency and Slump

02A.7.3.1 Every batch shall be tested for consistency or workability, except for zero slump concrete. Inspection Point

02A.7.3.2 The test for consistency or workability shall be completed within 15 minutes of the time of receipt of the ready-mixed concrete at site.

02A.7.3.3 Every batch shall be tested for temperature within 15 minutes of the time of receipt of the ready-mixed concrete at site. Inspection Point

02A.7.3.4 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 02A.4.

02A.7.4 Large Pours

02A.7.4.1 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. Review Point

02A.7.4.1.1 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

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record the concrete temperatures during hydration and temperature differentials across the sample.

02A.7.5 Placement

02A.7.5.1 Preparation Prior to Placement

02A.7.5.1.1 Before concrete is actually placed, formwork shall be inspected by the Engineer to ensure it has been cleaned and oiled. Inspection Point

02A.7.5.1.2 Temporary formwork openings shall be provided to facilitate inspection and such openings shall be later suitably plugged.

02A.7.5.1.3 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.

02A.7.5.1.4 All such embedments shall be correctly positioned and securely held in the forms to prevent displacement during placement and vibration of concrete. Inspection Point

02A.7.5.1.5 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. Inspection Point

02A.7.5.1.6 Reinforcement and other items to be cast in concrete shall have clean surfaces that shall not impair bond. Inspection Point

02A.7.5.1.7 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.

02A.7.5.1.8 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.

02A.7.5.2 Casting

02A.7.5.2.1 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. Review Point

02A.7.5.2.2 The Contractor shall prepare a detailed method statement for review by the Engineer.

02A.7.5.2.3 Concrete shall be transported and placed such that contamination, segregation or loss of the constituent materials does not occur.

02A.7.5.2.4 Concrete shall be placed in the required location/position, level, heights, etc. by pumping/ mechanically/etc.

02A.7.5.2.5 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.

02A.7.5.2.6 Concreting, once started, shall be continuous until the pour is completed. Inspection Point

02A.7.5.2.7 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.

02A.7.5.2.8 The thickness of each layer shall be such that it can be deposited before the previous layer has stiffened.

02A.7.5.2.9 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. Hold Point

02A.7.5.3 Compaction

02A.7.5.3.1 Conventional concrete shall be compacted during placement with approved vibrating equipment until the concrete has been consolidated to the maximum practicable

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density, is free of pockets of coarse aggregate and fits tightly against all formwork surfaces, reinforcement and embedded fixtures. Inspection Point

02A.7.5.3.2 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. Inspection Point

02A.7.5.3.3 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. Inspection Point

02A.7.5.4 Wet Weather

02A.7.5.4.1 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.

02A.7.5.4.2 If rain should interrupt concreting, the concrete shall be adequately protected.

02A.7.5.5 Hot Weather

02A.7.5.5.1 In the event that the temperature during the pour is forecast to exceed 35^{0}C, the Contractor shall assess the proposed pour using an approved method and shall propose mitigating measures for the Engineer's review. Review Point

02A.7.5.5.2 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

02A.7.5.5.3 Concreting shall not be carried out if the temperature of the concrete mix at the point of placement exceeds 32ºC.

02A.7.5.5.4 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.

02A.7.6 Curing

02A.7.6.1 All concrete shall be cured by keeping it continuously damp for the period of time required for complete hydration and hardening to take place. Inspection Point

02A.7.6.2 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.

02A.7.6.3 Extra precautions shall be exercised in curing concrete during hot weather as outlined herein.

02A.7.6.4 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.

02A.7.6.5 Fresh concrete shall be kept continuously wet for a minimum period of 10 days from the date of placing of concrete.

02A.7.6.6 Curing of exposed surfaces shall begin immediately after the concrete has hardened.

02A.7.6.7 Water shall be applied to unformed concrete surfaces within one hour of final set.

02A.7.6.8 Water shall be applied to formed surface immediately upon removal of forms.

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02A.7.6.9 Water flows shall be controlled so as to prevent erosion of freshly placed concrete.

02A.7.6.10 The quality of curing water shall be the same as that used for mixing concrete.

02A.7.6.11 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.

02A.7.6.12 For curing of concrete in pavements, side-walks, floors flat roofs or other level surfaces, the ponding method of curing is preferred.

02A.7.6.13 Special attention shall be given to edges and corners of the slab to ensure proper protection to these areas.

02A.7.6.14 Ponded areas shall be kept continuously filled with water during the curing period.

02A.7.6.15 All equipment and materials required for curing shall be ready for use before concrete is placed.

02A.7.7 Protection

02A.7.7.1 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. Review Point

02A.7.7.2 The concrete shall also be protected from other work in progress.

02A.7.7.3 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 02A.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 (if so designed)	28 days	100% Design Strength

02A.7.8 Finishing

02A.7.8.1 This section details the treatment of concrete surface for all structures.

02A.7.8.2 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.

02A.7.8.3 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. Inspection Point

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02A.7.8.4 All formed finished surfaces shall present a uniform and smooth appearance. Inspection Point

02A.7.8.5 All concrete shall be protected against damage until fully cured.

02A.7.8.6 The qualities of finishes required shall be as defined in Table F.4 of EN 13670 Execution of concrete structures.

02A.7.9 Bonding Mortar

02A.7.9.1 Concrete construction joints shall be covered with an approved bonding cement slurry immediately before concrete placement. Inspection Point

02A.7.10 Joints

02A.7.10.1 Construction Joints Review Point

02A.7.10.1.1 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.

02A.7.10.1.2 Where shown on the Drawings, recesses shall be formed in construction joints in order to form a key with adjacent concrete.

02A.7.10.1.3 Formwork to provide stop ends for vertical joints in reinforced concrete shall be firmly fixed and cut around the reinforcement.

02A.7.10.1.4 Concrete which passes through the stop ends shall, after setting, be removed.

02A.7.10.1.5 Retarding agents shall not be used on stop end forms.

02A.7.10.1.6 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.

02A.7.10.1.7 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.

02A.7.10.1.8 If this procedure is not possible, the laitance shall be removed with a combined jet of air and water.

02A.7.10.1.9 If the concrete is too hard, sand blasting, wire brushing or scabbling may be used with care.

02A.7.10.1.10 The prepared joint surface shall be cured using only fresh water.

02A.7.10.1.11 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.

02A.7.10.1.12 Special care shall be taken to butt the new concrete thoroughly against the old.

02A.7.10.1.13 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.

02A.7.11 Breaking Out Concrete

02A.7.11.1 The extent of concrete removal on repair works to existing structures shall be in accordance with the Drawings.

02A.7.11.2 Broken out concrete surfaces and exposed reinforcement shall be protected from salt water splash and spray, where applicable.

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02A.7.11.3 The period between breaking out existing concrete and placing new repair concrete shall be minimised and in no cases longer than 7 days.

02A.7.11.4 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.

02A.7.11.5 The Contractor shall submit details of his proposed method equipment and staff to be used for review prior to commencing work. Hold Point

02A.7.11.6 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. Review Point

02A.7.11.7 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.

02A.7.11.8 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. Review Point

02A.7.11.9 Bonding agents shall not be employed.

02A.8 TESTING AND INSPECTIONS

02A.8.1 Quality Parameters

02A.8.1.1 Characteristic Strength

02A.8.1.1.1 The specified characteristic strength of a designed mix shall be the 28-day compressive cube strength (N/mm^2) equal to or greater than the value in the performance criteria in section 02A.4.

02A.8.1.2 Mix Reference

02A.8.1.2.1 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.

02A.8.1.3 Water/ Cement Ratio

02A.8.1.3.1 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 02A.4, which is a free water/cement ratio.

02A.8.1.4 Chloride Content of Concrete

02A.8.1.4.1 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.

02A.8.1.4.2 The chloride content shall be measured in accordance with applicable Standards.

02A.8.1.5 Sulphate Content of Concrete

02A.8.1.5.1 The total sulphate content of the concrete mix by mass of sulphur trioxide by mass of cement shall not exceed 4.0%.

02A.8.1.6 Alkali Content of Concrete

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02A.8.1.6.1 The total acid soluble alkali content of the mix, expressed as equivalent sodium oxide, shall not exceed 3 kg/m^3 when measured as described in the British Cement Association document "Minimizing the risk of alkali aggregate reaction".

02A.8.2 Sampling and Testing of Aggregates

02A.8.2.1 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. Review Point

02A.8.2.2 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.

02A.8.2.3 From time to time or at time interval required by the Engineer, at least 5% of all samples shall be independently verified.

02A.8.3 Sampling and Testing of Water

02A.8.3.1 Water drawn from municipal water that is certified potable shall not require sampling or testing.

02A.8.3.2 Sampling and testing of other water used for concrete batching and curing shall conform with EN 1008.

02A.8.4 Sampling and Testing of Reinforcement

02A.8.4.1 Test Certificates

02A.8.4.1.1 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.

02A.8.4.1.2 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

02A.8.4.2 Reinforcement Samples for Independent Testing

02A.8.4.2.1 The Contractor shall, in the presence of the Engineer, cut samples from any reinforcing bars or fabric whenever the Engineer directs.

02A.8.4.2.2 Minimum sample length shall be 600mm or 20 times the bar diameter, whichever is greater.

02A.8.4.3 Testing

02A.8.4.3.1 The required properties of reinforcing steels shall conform with IS 1786 unless otherwise stated in the Employer's Requirements or applicable Standards.

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02A.8.5 Trial Mixes

02A.8.5.1 General

02A.8.5.1.1 The Contractor shall prepare a number of trial mixes using the approved aggregates and cement and, where applicable, approved admixtures.

02A.8.5.1.2 The Contractor shall make, cure and test specimens for strength and for all other tests as required by the Employer's Requirements.

02A.8.5.1.3 Specimens shall be cubes for each class of concrete in accordance with applicable Standards, cured in water at the ambient air temperature.

02A.8.5.1.4 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.

02A.8.5.2 Mixing

02A.8.5.2.1 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.

02A.8.5.2.2 The trial mixes shall be transported a representative distance before making the test cubes.

02A.8.5.3 Samples

02A.8.5.3.1 Nine test cubes shall be taken from three separate batches for each concrete mix design.

02A.8.5.3.2 From each set of nine cubes, three shall be tested at 7 days and three at 28 days.

02A.8.5.3.3 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.

02A.8.5.4 Mix Design

02A.8.5.4.1 The Contractor shall submit to the Engineer for review full details of trial mixes proposed for the Works, including:

a) Grading of the coarse and fine aggregates;

b) Ratio by weight of all constituents of the mix;

c) Compacting factor and slump test results;

d) Test cube/ cylinder results;

e) Water penetration test.

02A.8.5.4.2 No concrete shall be used in the Works until the test cubes have attained the required strength at the age specified.

02A.8.5.5 Calculations

02A.8.5.5.1 The Contractor shall supply to the Engineer copies of all calculations relevant to the determination of the proportions of each class of mix.

02A.8.6 Sampling and Testing of Concrete

02A.8.6.1 General

02A.8.6.1.1 Concrete samples shall be tested either at an on-site certified laboratory or an independent certified laboratory.

02A.8.6.1.2 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.

02A.8.6.1.3 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. Review Point

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02A.8.6.1.4 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.

02A.8.6.1.5 In all cases, the 28 days compressive strength specified shall solely be the criterion for acceptance or rejection of the concrete.

02A.8.6.1.6 The Engineer may relax the frequency of 28 days compressive strength testing, provided expected strength values at the specified early age are consistently met.

02A.8.6.1.7 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.

02A.8.6.1.8 The minimum frequency of sampling of concrete of each grade shall be in accordance with Table 02A.2 below:

Table 02A.2 - Sample Frequency

Concrete Quantity (m^3)	Minimum Number of Samples
<5	1
5-15	2
16-30	3
31-50	4
>50	4 + 1 sample/ additional 50 m^3

02A.8.6.1.9 At least one sample shall be taken from each shift.

02A.8.6.1.10 Three test specimens shall be made from each sample for testing at 28 days.

02A.8.6.1.11 Additional cubes may be required for various purposes such as:

a) to determine the strength of concrete at 3 and/or 7 days, or

b) at the time of striking the formwork, or

c) to determine the duration of curing, or

d) to check the testing error.

02A.8.6.1.12 Additional cubes may also be required for testing cubes cured by accelerated methods as described in applicable Standards.

02A.8.6.1.13 The specimen shall be tested as described in applicable Standards.

02A.8.6.1.14 The test strength of the samples shall be the average of the strength of three specimens.

02A.8.6.1.15 The individual variation shall not be more than (+/-) 15 percent of the average.

02A.8.6.1.16 Slump and temperature tests shall be carried out for every batch prior to placement.

02A.8.6.1.17 Slump and temperature testing shall be done immediately after sampling and also at the workface before the concrete is placed.

02A.8.6.1.18 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.

02A.8.6.2 Acceptance Criteria

02A.8.6.2.1 The concrete shall be deemed to comply with the strength requirement if:

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a) The mean strength determined from any group of four consecutive test results complies with the appropriate limits in Column 2 of Table 02A.3.

b) Any individual test result complies with the appropriate limits in Column 3 of Table 02A.3.

Table 02A.3 - Acceptance 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

02A.8.6.2.2 If the concrete is deemed not to comply based on Table 02A.3, the structural adequacy of the part affected shall be investigated and any consequential action needed shall be taken.

02A.8.6.2.3 Concrete of each grade shall be assessed separately.

02A.8.6.2.4 Concrete shall be assessed daily for compliance.

02A.8.6.2.5 Concrete for pavements shall include flexural strength tests to ensure the design assumptions used in calculations.

02A.8.6.2.6 The number of tests shall be approved by the Engineer (not less than 2 test every 1,000 m^2).

02A.8.6.2.7 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.

02A.8.6.2.8 Hardened concrete may be accepted after carrying out remedial measures to the satisfaction of the Engineer.

02A.8.7 Tests on Completion

02A.8.7.1 Immediately after stripping formwork, all concrete shall be carefully inspected and any defective work or small defects either removed or made good. Inspection Point

02A.8.7.2 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.

02A.8.7.3 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.

02A.8.7.4 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.

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02A.8.7.5 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.

02A.8.7.6 The cost of the conclusive tests shall be borne by the Contractor.

02A.8.7.7 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.

02A.8.7.8 The Contractor shall bear all costs of remedial works.

02A.9 DELIVERABLES

02A.9.1 Pre-construction Documentation

02A.9.1.1 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)

02A.9.1.2 Fabrication and construction shall not commence until the Engineer has reviewed the above documents.

02A.9.2 Delivery to Site

02A.9.2.1 The Contractor shall, on delivery of materials to the Site, submit to the Engineer the manufacturer's/suppliers associated documentation, with certified test results.

02A.9.2.2 Materials such as bundles of reinforcement, admixtures, etc. shall be clearly labelled to enable traceability.

02A.9.3 Inspection of Concrete Surfaces

02A.9.3.1 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.

02A.9.4 Records

02A.9.4.1 The Contractor shall submit to the Engineer manufacturer's/supplier's certifications and test results for all concrete components, reinforcement, fittings, etc.

02A.9.4.2 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.

02A.9.4.3 Records shall also include actual casting sequence and actual mix constituent quantities.

02A.9.4.4 Mix and ambient temperatures and wind speed shall be recorded.

02A.9.4.5 Copies of all records shall be supplied to the Engineer, within 24 hours of the recorded event.

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02A.10 DEFECTIVE CONCRETE

02A.10.1.1 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.

02A.10.1.2 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 Employer's Requirements

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PART A: CONCRETE AND REINFORCEMENT

APPENDIX I

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APPENDIX II

GLOSSARY

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GLOSSARY

Term / Abbreviation	Definition
ASR	Alkali Silica Reaction
BRE	Building Research Establishment
GGBS	Ground Granulated Blast-furnace Slag
ITP	Inspection Test Plan
PC	Portland Cement

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