



TRANSNET SOC LTD

**DCT BERTHS 203 TO 205 - RECONSTRUCTION, DEEPENING AND
LENGTHENING**

PORT OF DURBAN

SPECIFICATION – CONCRETE FOR MARINE CONSTRUCTION

1785-CO-000-C-SPC-0001 Rev T-01

12 OCTOBER 2023

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1.0 SCOPE

1.1 Project

This specification is a project specific technical specification for the DCT Berths 203 to 205 Reconstruction, Deepening and Lengthening Project in the Port of Durban.

1.2 Scope

The scope of this specification covers the Employer's requirements for the provision, placing, curing and testing of concrete in a marine environment, with specific emphasis on durability of concrete in the marine environment. It covers basic materials, Equipment, quality, manufacture, curing of the concrete, tolerances in workmanship, tests and acceptance criteria.

The specification covers the concrete requirements for the following *works*:

- a) Caisson manufacturing
- b) Precast element manufacturing
- c) Steel Fibre Reinforced Concrete (FSRC) for Rigid Inclusions
- d) In situ capping beam
- e) Service Tunnels
- f) Rear crane rail piles
- g) Rear crane rail beam
- h) Storm water, electrical, sewer and water services
- i) Concrete paving

The first section of the specification deals with general requirements which are applicable to all concrete work and subsequent sections deal with specific requirements which are over and above the general requirements and apply only to the specific section of work referenced.



2.0 NORMATIVE REFERENCES

2.1 Reference Documents

The *works* shall be carried out as specified in the following documents:

- a) This Specification
- b) Industry Codes, Standards and Specifications as listed in Section 2.2
- c) Employer's Project Specific Technical Specifications as listed in Section 2.3
- d) Project Drawings:
 - 1785-CO-030 series of drawings – Ground Improvements – Rigid Inclusions
 - 1785-CO-060 series of drawings – Caisson Quay Wall
 - 1785-CO-070 series of drawings – Return Quay
 - 1785-CO-090 series of drawings – Capping Beam and Service Tunnels
 - 1785-CO-100 series of drawings – Rear Crane Rail Piles and Beam
 - 1785-CO-120 series of drawings – Water Supply
 - 1785-CO-130 series of drawings – Sewer
 - 1785-CO-140 series of drawings – Electrical and C&I Infrastructure
 - 1785-CO-150 series of drawings – Storm Water
 - 1785-CO-160 series of drawings – Paving
- e) Method statement prepared by the Contractor, as described in Section 4.1.

2.2 Standard Specifications

The *Contractor* shall provide and maintain current copies of all the standard specifications referred to herein below on the site for reference by both parties.

The governing standard for this specification shall be:

- a) SANS 2001-CC1:2012 Construction Works – Concrete Works (Structural), which shall apply in its entirety except for the variations and additions detailed in the specification clauses below.

The provision, placing, curing and testing of concrete in a marine environment shall comply with the following standard specifications:

- a) SANS 50197-1:2013/EN 197-1:2011 – Cement – composition, specifications and conformity criteria - Part1: Common cements
- b) SANS 55167 – Portland cement extenders – Part 1: Ground granulated blast furnace slag
- c) SANS 50450 – Portland cement extenders – Part 2: Fly ash
- d) SANS 53263 – Portland cement extenders – Part 3: Condensed Silica Fume
- e) SANS 51008:2006/EN 1008:2002 (2012-11-23) – Mixing water for concrete, Specification for sampling, testing and assessing the suitability of water
- f) SANS 1083:2018 Edition 2.6 – Aggregates from natural sources – Aggregates for concrete
- g) SANS 5836:2007 (2013-03-15) – Drying shrinkage of aggregates
- h) SANS 6085:2006 (2012-04-20) – Drying shrinkage of concrete
- i) Fulton's Concrete Technology – Ninth Edition
- j) ASTM C494/C494M-15a – Standard specification for Chemical Admixtures for Concrete
- k) SANS 50934-2:2011/EN 934-2:2009 – Concrete admixtures for concrete, mortar and grout. Part 2: Concrete admixtures, definitions, requirements, conformity, marketing, labelling
- l) SANS 423:2016/ASTM C309-2011 – Standard Specification for Liquid Membrane-Forming Compounds for Curing Concrete

- m) ASTM C1152/1152M-04 (2012) e1 – Standard Test Method for Acid-Soluble Chloride in Mortar and Concrete
- n) SANS 5026:2015/EN 206:2014 – Concrete – Part 1: Specification, performance, production and conformity
- o) SANS 5863:2006 (2012-04-26) – Concrete Tests – Compressive Strength of Hardened Concrete
- p) SANS 5864:2006 (2012-04-26) – Concrete Tests – Flexural Strength of Hardened Concrete
- q) BS EN 14889-1:2006 Fibres for concrete — Part 1: Steel fibres — Definitions, specifications and conformity
- r) COTO Standard Specification for Road and Bridge Works for South African Road Authorities
- s) ACI 313-97 – Standard Practices for Design and Construction of Concrete Silos and Stacking Tubes
- t) DNV-03-C502 – Offshore Standard, Offshore Concrete Structures, 2012
- u) BS EN 14651:2005 & A1 2007 Test Method for Metallic Fibre Concrete Measuring the Flexural Tensile Strength (Limit of Proportionality (LOP) residual)
- v) BS EN 14889-1:2006 – Fibres for Concrete Steel Fibres. Definitions, Specifications and Conformity
- w) SANS 5861-1:2006 (2012-03-23) – Concrete Tests – Mixing Fresh Concrete in the Laboratory
- x) SANS 5861-2:2006 (2012-03-23) – Concrete Tests – Sampling of Freshly Mixed Concrete
- y) SANS 5861-3:2006 (2012-03-23) – Concrete Tests – Making and Using Test Specimens
- z) BS EN 12699:2015. Execution of special geotechnical work – Displacement piles
- aa) BS EN 206:2013. Concrete. Specification, performance, production and conformity

2.3 Employer's Project Specific Specifications and Standards

The provision, placing, curing and testing of concrete in a marine environment shall also comply with the following Project Specific Specifications and Standards:

- a) 1785-CO-000-C-SPC-0002 – Caisson Construction and Placement
- b) 1785-CO-000-C-SPC-0003 – Cope, Service Tunnels, Quay Furniture and Services
- c) 1785-CO-000-C-SPC-0007 – Paving
- d) 1785-CO-000-C-SPC-0010 – Ground Improvement: Rigid Inclusions and Foundation Stone Bed (Caisson Load Transfer Platform)
- e) Project Environmental Specifications (PES) as contained in the Works Information and annexures



3.0 DEFINITIONS

All definitions of responsibilities shall be in accordance with the NEC Engineering and Construction Contract (ECC) for the construction of the *works*.

Where the standard specifications referenced in this specification refer to the “Engineer”, replace this term with the term “*Supervisor*”.

For the purpose of this specification, the definitions and abbreviations given in SANS 2001-CC1:2012, together with the following definitions shall apply:

3.1 Slip-Forming

The term ‘Slip-forming’ refers to the process of constructing a vertical structure using a continuously moving form. Slip-forming is also referred to as ‘Sliding’ in SANS 2001-CC1:2012 and all such clauses are applicable to the slip-forming operation.

3.2 Method Statements

Method statements shall be compiled by the Contractor for all activities and for all stages of the establishment, casting, launching, towing and placement work. The method statements shall be submitted to the Supervisor for acceptance three weeks in advance of the particular activity being undertaken. Full details of all proposed Equipment (including temporary *works*) and methods shall be provided for acceptance by the Supervisor. No activity shall commence until the method statement has been accepted by the Supervisor.

3.3 Abbreviations

ASR	Alkali – Silica Reaction
FA	Fly Ash
FACT	Fine Aggregate Crushing Test
GGBS	Ground Granulated Black Furnace Slag
GGGS	Ground Granulated Corex Slag
SFRC	Steel Fibre Reinforced Concrete
W/C	Water Cement Ratio



4.0 GENERAL REQUIREMENTS APPLICABLE TO ALL CONCRETE WORKS

4.1 Trial Mixes, Method Statements and Acceptance

4.1.1 Prior to casting any concrete included in the permanent *works*, the *Contractor* shall:

- a) Submit to the *Supervisor* for acceptance the samples that he proposes to use for the concrete and shall furnish evidence (test certificates and results) that the aggregates, cement, water, admixtures and curing compounds comply with the requirements of the material clauses below;
- b) Submit to the *Supervisor* for acceptance details of proposed concrete mix design and program of trial mix production;
- c) Undertake laboratory trial mix designs;
- d) Undertake site trials of the specified grades of concrete using the concrete from the trial for site establishment or temporary *works* purposes:
 - Trial mixes shall be produced under full-scale production conditions using representative samples of cement and aggregates.
 - Three separate batches shall be produced each on a separate day. The workability of each batch shall be determined and at least 6 cubes shall be made from each batch. Three shall be tested at 7 days and the other three tested at 28 days.
 - The 28-day cube results from this site trial confirming that the concrete meets the specified strength and slump requirements shall be made available to the Supervisor prior to any casting of concrete in the permanent *works*.
- e) Submit a detailed method statement of the concrete construction method to the Supervisor for approval 2 weeks prior to commencing any concrete *works*. The method statement shall include but not be limited to:
 - Method of material storage, concrete batching, transportation, and delivery
 - Quality control procedures for batching of concrete
 - Details of falsework, formwork and methods of achieving specified finishes
 - Details for positioning and securing cast-in items to specified tolerances
 - Details of methods of placement for each structure or type of structure including any proposals for the use of spouts, chutes or pumps as a means of placing concrete.
 - Details of vibration equipment and techniques
 - Method and duration of curing
 - Quality control procedures for traceability of concrete batches vs. elements cast.

4.2 Materials

4.2.1 Cementitious Binders

- 4.2.1.1 All cements used for concrete work shall comply with SANS 50197-1.
- 4.2.1.2 All cement extenders used for concrete work shall comply with SANS 55167, SANS 50450-2 or SANS 53263.
- 4.2.1.3 The cement types given below are acceptable for use in the *works*, however the proportion of extender in factory blended cements shall conform to the requirements of set out in Table 4.1: below.
- 4.2.1.4 No masonry cements shall be used for concrete work, even if the strength designations are the same as for common cements.
- 4.2.1.5 Acceptable cement types are:
 - a) CEM I 42,5 Portland Cement
 - b) CEM I 52,5 Portland Cement
 - c) CEM I 42,5R Portland Cement, rapid hardening
 - d) CEM I 52.5R Portland Cement, rapid hardening

- | | | |
|----|------------|--------------------------------------|
| e) | CEM II/B-V | Portland fly ash cement (Siliceous) |
| f) | CEM II/B-W | Portland fly ash cement (Calcareous) |
| g) | CEM III/A | Blast furnace cement |

4.2.1.6 All cement shall be fresh and shall be delivered either in unbroken water resistant bags containing approximately 50 kg cement, or in bulk containers specifically designed for the purpose, bearing the manufacturer's name and the date of manufacture.

4.2.1.7 Cement shall be stored off the ground in a suitable dry shed or in a self-clearing silo and shall be protected against deterioration. Silos shall be provided with a fluidizing facility and shall be of the single compartment type.

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

4.2.1.9 The various types of cement shall be handled, identified, and stored separately.

4.2.2 Water for Concrete

4.2.2.1 Water that is to be used for mixing concrete and curing concrete and any other operation shall at all times comply with the requirements of BS EN 1008:2002.

4.2.2.2 It shall be fresh, clean, potable and free from injurious amount of acids, alkalis, organic matter and other substances that may impair the strength or durability of concrete.

4.2.2.3 Requirements for testing of the water including the frequencies for testing are provided in clauses 5 and 6 of BS EN 1008:2002.

4.2.2.4 The pH of water used in concrete work shall be not less than 5.0 and not more than 8.0. Under no circumstance shall seawater be used for mixing or curing concrete.

4.2.2.5 The chloride and sulphate content of the water shall be included in the assessment of the total chloride and sulphate content of the proposed concrete mix.

4.2.3 Aggregates

4.2.3.1 All course and fine aggregates shall comply with the requirements of SANS 1083:2018.

4.2.3.2 Under no circumstances and for no portion of the *works* is the use of plums in concrete permitted.

4.2.3.3 The drying shrinkage of the fine and coarse aggregate, when tested in accordance with SANS 5836, shall not exceed 175% of that of the reference aggregate for sand and 150% of that of the reference aggregate for stone.

4.2.3.4 The drying shrinkage of concrete shall not exceed 0.040% when tested in accordance with the requirements of SANS 6085.

4.2.3.5 The flakiness index of the stone as determined by SANS 1083, shall not exceed 35.

4.2.3.6 The *Contractor* shall ensure that the total equivalent Na₂O content in the concrete mix per m³ is such that it is below the threshold value, as prescribed in Table 10.1 of Fulton's Concrete Technology – 9th Edition [% Na₂O equivalent = % Na₂O + (0,658 x % K₂O)].

4.2.3.7 The limits prescribed in Table 10.1 apply only to CEM I cement. For CEM II and CEM III cements or for blends of CEM I with extenders, the active Na₂O equivalent must be calculated depending on the source and quantity of the major additional constituents and the alkaline content of the clinker in accordance with section 10.8 of Fulton's Concrete Technology – 9th edition.

4.2.3.8 The *Contractor* shall submit, prior to construction, a laboratory report by a certified laboratory confirming compliance with the requirements for preventing ASR in the concrete.



4.2.3.9 Coarse and fine aggregates shall be delivered to the Site or to the mixing plant by means that prevent contamination due to environmental effects, if necessary in covered containers, and shall be stored separately. Care shall be exercised in the handling and storage of the aggregates to prevent the segregation of the various particles and to prevent contamination from deleterious materials. The *Contractor* shall ensure that aggregates are not located in the vicinity of any ablution facilities.

4.2.3.10 Different aggregates shall be stockpiled separately and dividers provided to prevent mixing.

4.2.4 Admixtures

4.2.4.1 Any admixture used shall comply with the requirements of either SANS 50934-2:2011 / EN 934-2:2001 or ASTM C494/494M-15a.

4.2.4.2 Admixtures are permitted, provided that the results of trial tests which demonstrate their suitability and the following are made available:

- a) the trade name of the admixture, its source and the manufacturer's recommended method of use;
- b) typical dosages and possible detrimental effects of under-dosages and over-dosages;
- c) whether compounds likely to cause corrosion of the reinforcement or deterioration of the concrete (such as those containing chloride, in any form, as an active ingredient) are present and, if so, the chloride content of admixtures, expressed as a mass fraction of chloride ions or expressed as an equivalent mass; and
- d) fraction of anhydrous calcium chloride.

4.2.4.3 Admixtures will only be permitted if the *Contractor* demonstrates to the satisfaction of the *Supervisor* that they do not lead to a reduction in strength, additional shrinkage, bleeding, or any other undesirable effects. If the use of admixtures is permitted, they shall be used strictly in accordance with the manufacturer's instructions and any method statement agreed with the *Supervisor* after site trials have been carried out.

4.2.4.4 Admixtures containing chlorides will not be permitted in reinforced concrete.

4.2.4.5 Air-entraining admixtures will not be permitted in reinforced concrete.

4.2.5 Curing Compound

4.2.5.1 In all cases where a concrete curing compound is used, the curing compound shall be grey or white pigmented membrane forming material complying with SANS 423:2016 / ASTM specification C309-11, except that the maximum permissible water loss in the test shall be 0.40 kilograms per square metre.

4.2.5.2 Alternatively, the concrete curing compound shall be acceptable if the treated concrete retains 90% or more of its mixing water when subject to the test set out in BS 8110: Part 1, Clause 6.6 (c).

4.2.5.3 Note that the application of a curing compound is not a permitted form of curing for steel reinforced concrete and is only permitted for mass/unreinforced concrete (refer to section 4.5.12 below).

4.2.6 Grade of Concrete

4.2.6.1 Unless shown otherwise on the drawings, the grade of the concrete shall be as follows:

- a) Precast elements – Grade 45
- b) Reinforced in-situ elements including caissons – Grade 40
- c) Rigid Inclusions – Grade 45
- d) Paving – Grade 35



4.3 Formwork

4.3.1 General

4.3.1.1 The formwork surfaces shall be as follows:

- a) All exposed concrete surfaces require a smooth finish to a degree of Accuracy II. The base and outer walls of the caisson are considered exposed surfaces.
- b) All concealed and internal surfaces not exposed to view require a rough finish to a degree of Accuracy II.

4.3.1.2 The *Contractor* shall take particular care to ensure that formwork joints are tight enough to prevent leakage of cement mortar. Shutters that are damaged, or that leave a surface that is unacceptable to the *Supervisor*, shall be removed and repaired or discarded. No metal part of any device for securing forms is to remain within the specified concrete cover.

4.3.2 Design and Construction of Formwork and Falsework

4.3.2.1 The design and drawings for formwork and falsework shall be submitted for review.

4.4 Reinforcement

4.4.1 Bending

4.4.1.1 Bars may be bent hot in accordance with clause 4.4.1.3 and 4.4.1.4 of SANS 2001-CC1:2012.

4.4.2 Fixing

4.4.2.1 Welding of bars is permitted for fixing in accordance with clause 4.4.2.2 b) of SANS 2001-CC1:2012.

4.4.3 Cover

4.4.3.1 Minimum concrete cover to all steel reinforcement shall be as shown on the drawings and maintenance of this minimum cover during casting of concrete shall be strictly enforced. In addition to pre-pour inspections, the *Supervisor* shall use a cover meter to check compliance with the cover requirements. Concrete, which is cast with insufficient cover to the reinforcement shall be declared a defect and shall be corrected by the *Contractor* in accordance with clause 43 of the NEC ECC 3 Core Clauses.

4.4.3.2 Cover blocks used to ensure the cover to reinforcement shall be made of cement mortar using cement binders in the same proportions as the main concrete mix. They shall be dense and have a minimum 28 day crushing strength of 50 MPa, and shall be cured in water for at least 14 days before being used. Spacer blocks made of plastic will not be permitted.

4.5 Quality of Concrete

4.5.1 General

4.5.1.1 Before the start of concrete work on site, the *Contractor* shall submit a quality assurance plan which will ensure compliance with specification and provide acceptable documentary proof that all specified operations have been carried out satisfactorily. The quality assurance plan shall make provision for intervention points, to be agreed with the *Supervisor* for inspection of the *works*.

4.5.1.2 This specification prescribes the strength requirements, maximum and minimum binder contents, required extender content and maximum water binder ratios. In terms of coarse and fine aggregate proportions, this specification is non-prescriptive.

4.5.1.3 The cementitious binder content for any class of concrete shall not exceed 450 kg/m³ of concrete.

4.5.2 Workability

- 4.5.2.1 Pumping of concrete is permitted.

4.5.3 Chloride and Sulphate Content

- 4.5.3.1 The total chloride content (acid soluble) arising from all ingredients in a mix including cement, water and admixtures shall not exceed 0.15% chloride ion as a percentage of the mass of cement in the mix.
- 4.5.3.2 Prior to the use of a concrete mix for the permanent *works*, a sample of concrete from a trial mix shall be tested for acid-soluble (total) chloride ion content in accordance with ASTM C1152. Provided the chloride content does not exceed the specified limit, no further testing is required unless the mix ingredients are changed.

4.5.4 Durability

- 4.5.4.1 In order to enhance durability and notwithstanding strength considerations, the concrete mixes shall be in accordance with Table 4.1: , noting the following:
- Total binder content is the sum of the Portland cement and any extenders used.
 - GGBS – Ground Granulated Blast Furnace Slag.
 - GGCS – Ground Granulated Corex Slag.
 - FA – Fly Ash.
 - W/C ratio is the free water divided by the cementitious binder content.
 - Water-reducing admixtures may be used to improve workability (See also Clause 4.2.4 above). The water cement ratio shall include the water content of admixtures.
 - Factory blended cements (CEM II/B-V, CEM II/B-W or CEM III/A) will be accepted provided that they conform to one of the blends specified in the table. The Contractor shall supply certification thereof.
 - Blends of CEM I and Condensed Silica Fume (CSF) are not acceptable for steel reinforced concrete.

Table 4.1: Concrete Mixes

Concrete Type/ Structural Element	Exposure Class (EN 206-1:2013)	28 Day Characterist ic Strength (MPa)	Total Binder Content kg/m ³		Required extender content % of total binder content		Max Water/ Binder Ratio
			Min	Max	FA (Min/Max)	GGBS / GGCS (Min/Max)	
Reinforced Concrete (Precast)	XS3	45	340	450	30% / 30%	50% / 50%	0.45
Reinforced Concrete (In- situ)	XS3	40	340	450	30% / 30%	50% / 50%	0.45
Cast In situ piles	XS3	40	340	450	30% / 30%	50% / 50%	0.45
Rigid Inclusion Concrete	XS3	45	340	450	30% / 30%	50% / 50%	0.45
Mass Concrete Paving	X0	35	320	420	0% / 15%	0% / 15%	0.53

4.5.5 Batching

- 4.5.5.1 All aggregates shall be precisely measured by mass using approved and certified precision weigh-batching equipment.

4.5.6 Mixing

- 4.5.6.1 The use of ready-mixed concrete is permissible.
- 4.5.6.2 No water shall be added to the mix after it has left the ready mixed concrete plant. Each delivery shall be tested at the site for workability. (Concrete not complying with the Specification must be removed from site and may not be tampered with and returned).

4.5.7 Potential Heat Generation

- 4.5.7.1 Measures, subject to the acceptance of the *Supervisor*, shall be applied to reduce heat development in concrete of which the minimum dimension to be placed during a single pour is larger than 600 mm, and the cement content exceeds the values given in Table 4.2

Table 4.2: Heat Generation Limiting Cement Contents

Structural Element	Cement Types I and III/A (kg/m ³)	Cement Types II/B-V and II/B-W (kg/m ³)
Reinforced Concrete	400	450
Prestressed Concrete	500	550

4.5.8 Transportation of Concrete

- 4.5.8.1 The *Contractor* is made aware of possible traffic congestion en-route to site and shall plan the delivery of concrete to site accordingly. No compensation shall be entertained for delays resulting from traffic congestion.

4.5.9 Placing

4.5.9.1 Pre-pour Inspections and Approvals

- 4.5.9.1.1 No concreting shall commence in any portion of the *works* until the preparations have been accepted by the *Supervisor*. Sufficient notice shall be given to the *Supervisor* to inspect and accept the work prior to concrete manufacture. No manufacture is to commence until written acceptance has been given to proceed.
- 4.5.9.1.2 Concrete shall not be placed in the *works* unless the *Supervisor's* Representative is present and the fixing of all formwork and reinforcement has been completed and accepted by the *Supervisor*.
- 4.5.9.1.3 All surfaces shall be free of dust and standing water.

4.5.9.2 Underwater concrete

- 4.5.9.2.1 All pours of concrete between tide levels shall be carried out in the dry and the top surface blanketed before being covered by the rising tide. Placing of concrete shall commence on a falling tide after the tide level has fallen below the base of the pour.
- 4.5.9.2.2 Casting concrete underwater is subject to the approval of the *Supervisor* with respect to the methods, equipment and materials that the *Contractor* intends to use. Use of a concrete admixture such as Sika UCS-01 ZA or other similar approved proprietary admixture to minimise the washout of cement paste shall be used in accordance with the Suppliers specification.

- 4.5.9.2.3 Unless otherwise permitted, the technique adopted for placing of concrete underwater and any dewatering shall be designed to prevent the washing out of cement from the concrete mixture, minimise the segregation of materials and the formation of laitance, and prevent the flow of water through or over new concrete less than 24 hours old.
- 4.5.9.2.4 After commencement, the placing of concrete underwater shall be continuous until completion, unless otherwise permitted.
- 4.5.9.2.5 No vibration shall be carried out until the top of the concrete is above water or tide level. For concrete totally cast below water level, no vibration will be allowed.
- 4.5.9.2.6 The maximum size of aggregate shall be 38 mm and the aggregates shall be well graded.
- 4.5.9.2.7 The bed shall be cleaned of silt and loose material, and must be passed by the *Supervisor* before concrete is placed.

4.5.9.3 Depositing Concrete by Tremie

- 4.5.9.3.1 The top section of the Tremie shall consist of a hopper of greater capacity than the pipe. The tremie shall be sturdily constructed of steel, and be not less than 200 mm in diameter. It shall be strong enough to withstand the full hydrostatic pressure, even if a partial vacuum develops in the pipe, and shall be completely watertight.
- 4.5.9.3.2 The lower end of the Tremie shall be equipped with an approved automatic check valve which shall be watertight.
- 4.5.9.3.3 For initial filling the Tremie shall have the automatic check valve closed and filling shall take place in such a manner as to prevent air locks. An initial 'Slush' mix is to be used in order to lubricate the pipe. This mix which will be less dense than the balance of the concrete will rise to the surface and be discarded.
- 4.5.9.3.4 When concrete is deposited the Tremie shall penetrate the concrete bed and shall be slowly raised to discharge a uniform flow of concrete. The end of the Tremie shall be under concrete during the whole operation.
- 4.5.9.3.5 Concreting shall continue to such a point that laitance can be removed, and a sound surface left at the final finished level.

4.5.9.4 Depositing concrete by pumping

- 4.5.9.4.1 Placing of concrete by pumping is permitted.
- 4.5.9.4.2 The same conditions and criteria as for depositing by Tremie as described in 4.5.9.3 apply.

4.5.10 Compaction

- 4.5.10.1 The concrete shall be compacted into a dense impermeable mass without segregation, bleeding or plastic cracking. Subsequently, the concrete shall be durable and cracks in hardened concrete shall not exceed 0.15 mm in width. Surface crazing or other types of surface pattern cracking will not be accepted.
- 4.5.10.2 The concrete shall be compacted with immersion vibrators used by properly trained and supervised operators. Vibrators shall penetrate the full depth of the layer of concrete and where the underlying layer is of fresh concrete shall enter and re-vibrate that layer to achieve effective knitting together.
- 4.5.10.3 Vibrators shall not be allowed to remain in contact with the reinforcement or formwork. Over and under vibration shall be avoided and vibrators shall be withdrawn slowly to prevent void formation.
- 4.5.10.4 Care shall be taken to compact the concrete fully around reinforcement but without causing displacement of the bars.
- 4.5.10.5 Hand compaction will not be permitted.

- 4.5.10.6 Sufficient vibrators shall be provided at each pour location to ensure that the concrete is fully compacted without delay. At least one reserve vibrator and power source shall be provided on site and not less than one reserve for every three in use at one time.
- 4.5.10.7 Immediately before the mixing and pouring of concrete each day the necessary vibrators shall be started and tested to the satisfaction of the *Supervisor*. Undue difficulty in starting a vibrator shall be sufficient grounds for rejection. External vibrators shall not be used without written approval.
- 4.5.10.8 Care shall be taken to prevent men engaged in placing concrete from introducing foreign matter into the concrete from their footwear or in any other way and, where concrete is placed directly against the surfaces of excavations, any softened material shall first be removed.
- 4.5.10.9 In-situ concrete shall be well compacted to a minimum of 98% of the density of the relevant cubes.

4.5.11 Joints

- 4.5.11.1 No construction joints are permitted in the caisson slip form/sliding operation.
- 4.5.11.2 Construction joints are required in the in situ capping beam and service tunnels.
- 4.5.11.3 It is essential that a good bond is achieved between casts at construction joints. The joint surface of the concrete is to be roughened while still green by means of brush and water spray to expose the coarse aggregate. Retarders may be used on stop-ends, which should be removed after 12 hours for green cutting. Mechanical roughening of hardened concrete using power tools will not be permitted as it may break or dislodge the coarse aggregate.
- 4.5.11.4 All surfaces must be cleaned and kept continuously wet for 24 hours before pouring of the adjoining cast. Unless otherwise shown on the drawings, the exact position of horizontal construction joints shall be marked on the formwork by means of grout checks in order to obtain truly horizontal joints.
- 4.5.11.5 Stub columns, stub walls and stays on footings shall be cast integrally with the footings and not afterwards, even where another class of concrete is being used.
- 4.5.11.6 Joint lines shall be so arranged that they coincide with features of the finished work.
- 4.5.11.7 At contraction joints (joints having no reinforcement passing through the joint), no bond is required between casts. Contraction joints shall be smooth, and shall be coated with an approved bond-breaker applied to the older surface prior to casting the newer concrete.
- 4.5.11.8 The *Supervisor's* prior written acceptance must be obtained before the adjoining concrete is cast.
- 4.5.11.9 Proprietary bonding compounds between old and new concrete may be used.

4.5.12 Curing and Protection

- 4.5.12.1 In order to enhance the long term durability of the concrete in the marine environment it is essential that it is correctly cured so that adequate hydration of the cement and extenders may take place.
- 4.5.12.2 All water for curing shall be clean, fresh water and under no circumstances will seawater be permissible.
- 4.5.12.3 The curing period for concrete containing CEM I only shall be 7 days. The curing period for concrete's containing CEM I plus cement extenders (GGBS, FA) shall be 10 days. The period will start on completion of the concrete pour and for formed surfaces shall include the time for which forms are still in place after the pour.
- 4.5.12.4 The *Supervisor's* prior written acceptance of the curing method to be used must be obtained before any concrete is cast.



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- 4.5.12.5 Concrete, of which the adequacy of the curing is not in compliance with this specification, shall be declared a defect and shall be corrected by the *Contractor* in accordance with clause 43 of the NEC ECC core clauses.
- 4.5.12.6 After formwork has been removed and as soon as it is practicable all concrete shall, subject to provisions of the adverse weather conditions, be protected from contamination and loss of moisture.
- 4.5.12.7 When the wind velocity exceeds 5 m/s and/or the ambient temperature is above 25°C and/or the relative humidity is below 60%, the initial 24 hour curing of concrete surfaces not covered by formwork shall be carried out by ponding, covering with constantly wetted sand or mats, or continuous spraying as detailed below.
- 4.5.12.8 The following curing methods are permissible for plain/unreinforced Concrete:
- Retaining forms in place on vertical surfaces provided they are made with non-absorbent facing materials. The forms shall be not more than 10°C cooler than the concrete and not more than the concrete curing temperature.
 - Ponding of water on horizontal surfaces. Curing water shall be fresh and not be more than 10°C cooler than the concrete on which it is to be applied in order to avoid surface cracking.
 - Covering with sand, earth, straw, sawdust, cotton, jute, burlap or hessian or similar moisture retaining materials. The materials shall be kept continually moist and shall not be allowed to dry out as alternate wetting and drying is detrimental to the curing process. The material shall be free of injurious amounts or substances such as sugar or fertiliser that may harm the concrete or cause discoloration.
 - Sprinkle or spraying with water. This may be done at frequent intervals provided that the concrete surface remains continuously moist and is not allowed to dry out between wetting. Erosion of the fresh concrete surface must be avoided.
 - Covering with plastic sheeting, waterproof or other curing paper. The covering material shall be firmly and continuously held in place along its edges such that the concrete surface is not allowed to dry out. Care must be taken not to tear, puncture or otherwise disrupt the continuity of the curing film. Plastic film shall not be black, white or clear.
 - Liquid membrane-forming curing compounds, which comply with the requirements of 4.2.5 may be used. Only resin type compounds will be permitted. The formulation must be such as to form a moisture retentive film shortly after being applied and must not be injurious to Portland cement paste. White or grey pigments or dyes must be incorporated to enable the compound to be visible on the surface for inspection purposes.
 - For unformed surfaces the compound shall be applied after finishing and as soon as the free water on the surface has disappeared and no water sheen is visible, but not so late that the liquid curing compound will be absorbed into the concrete.
 - For formed surfaces, when forms are removed, the exposed concrete surface shall be wet with water immediately and kept moist until the curing compound is applied. Immediately prior to application, the concrete shall be allowed to reach a uniformly damp appearance with no free water on the surface. Application of the compound should then begin at once. The compound should be applied at a uniform rate with two applications at right angles to each other to ensure complete coverage, and may be applied by hand or power sprayer. Pigmented compounds must be adequately stirred to assure even distribution of the pigment during application, unless the formulation contains a thixotropic agent which prevents settlement.
 - The compound manufacturer must supply a certificate confirming compliance with 4.2.5 and the manufacturer's directions with respect to preparation and application. The manufacturer's preparation and application directions for the compound must be strictly adhered to.
 - The total application rate shall be as specified by the Manufacturer, or 0,30 litres per square metre,



whichever is the greater.

- k) In the case of concrete surfaces with run-off problems, it may be necessary to apply more than one coat of membrane forming curing compound to obtain the specified total or cumulative application rate.

The following curing methods are permissible for steel reinforced concrete:

- a) Covering with burlap or hessian or similar moisture retaining materials. Requirements as given above for plain concrete.
- b) Sprinkling or spraying with water. Requirements as given above.
- c) Releasing the forms slightly and allowing a flow of water between the form and the concrete.
- d) Curing methods using sealing materials such as plastic or liquid membrane forming compounds is **NOT** permitted for steel reinforced concrete structures due to the low W/C ratio of the concrete mix. The water provided by the moist curing is required for completion of the hydration of the concrete in the cover layer.

4.5.13 Concrete Surfaces

- 4.5.13.1 All exposed concrete surfaces shall have a neat, smooth, even and uniform finish, free from any honeycombing and blow holes.

4.5.14 Records

- 4.5.14.1 The *Contractor* shall maintain the following daily records for every part of the concrete work and make these available at all times during the progress of the work for inspection by the *Supervisor*:
 - a) Date and times during which concrete was placed
 - b) Identification of the part of structure in which the concrete was placed
 - c) Mix proportions and specified strength
 - d) Type and brand of cement
 - e) Slump of the concrete
 - f) Identifying marks of test cubes made
 - g) Curing procedure applied to concrete placed
 - h) Times when shuttering was stripped and props were removed
 - i) Date of dispatch of the cubes to the testing laboratory
 - j) Cube test results

5.0 ADDITIONAL REQUIREMENTS FOR STEEL FIBRE REINFORCED CONCRETE (SFRC) FOR RIGID INCLUSIONS

5.1 General

- 5.1.1 Notwithstanding the clauses below, the *Contractor* shall be responsible for the design of the fibre reinforced concrete mix in terms of determining the type of fibre and dosage required to achieve the required performance.

5.2 Materials

- 5.2.1 The fibres shall be cold drawn, hooked end, high strength steel fibres conforming to the requirements of BS EN 14889-1.
- 5.2.2 The length, diameter, aspect ratio, tensile strength ($R_{m,nom}$) shall be as per the supplier's recommendations to meet the performance specification.

5.3 Quality of Concrete

5.3.1 Flexural Strength

- 5.3.1.1 In addition to the strength requirements detailed above in section 4.0, the SFRC shall have a characteristic residual flexural tensile strength $f_{R,3} = 6.0$ MPa when tested in accordance to BS EN 14651

5.3.2 Workability and Uniformity

- 5.3.2.1 The SFRC shall be easily pumpable without causing blockages in the Rigid Inclusion Equipment
- 5.3.2.2 Dosages of fibre, fibre shape and fibre coatings shall be such that blockages during pumping are avoided and lump formation is avoided. A fibre dosage of less than or equal to 45 kg/m³ is recommended however a higher dosage is acceptable provided the *Contractor* demonstrates that the concrete remains pumpable.
- 5.3.2.3 The fibres shall be mixed and placed in accordance with the supplier's recommendations to ensure that the fibres are distributed uniformly throughout the SFRC element.

5.4 Testing

5.4.1 Frequency of Testing

- 5.4.1.1 In addition to the cube testing required, six beam samples per 100 m³ of SFRC shall be cast and tested according to BS EN 14651.

5.4.2 Acceptance of Strength Concrete

- 5.4.2.1 The cross sectional area of the beam being tested is very small in comparison to the element and therefore there is likely to be a high variance of the number of fibres crossing the test area. A variation of results is therefore likely.
- 5.4.2.2 For this reason, the average value of a set of 6 beams is deemed as a single result and the standard deviation and characteristic strengths shall be calculated using the averaged values from a series of sets.

5.4.3 Trial Mixes

- 5.4.3.1 The *Contractor* shall undertake trial mixes of the SFRC in accordance with 4.1 above.
- 5.4.3.2 In addition, the *Contractor* shall construct two test Rigid Inclusions as detailed in specification 1785-CO-000-C-SP-0010. The samples taken from the test piles shall be tested for uniformity and distribution of fibres by visual inspection and by density.

6.0 ADDITIONAL REQUIREMENTS FOR CONCRETE FOR PAVING

6.1 Aggregate Size

6.1.1 The nominal size of the coarse aggregate shall be 37.5 mm, plus one or more of the following:

- 19.0 mm
- 13.2 mm
- 9.5 mm

6.1.2 Coarse aggregate shall comply with the 10% FACT values specified for aggregate used in concrete subject to abrasion.

6.2 Concrete Strength Requirements

6.2.1 The specified compressive strength shall be the highest of the following four values:

- 35 MPa at 28 days; or
- $0.85 \times f_{c1}$ where f_{c1} is the 28 day compressive strength corresponding to a 28-day flexural strength of 4.5 MPa.
- $0.85 \times f_{c2}$ where f_{c2} is the 28 day compressive strength corresponding to a water cement ratio of 0.53.
- $0.85 \times f_{c3}$ where f_{c3} is the 28 day compressive strength corresponding to a cement content of 320 kg / m³.

6.2.2 f_{c1} , f_{c2} , and f_{c3} shall be the 28 day compressive strengths determined from laboratory mixes as detailed below.

6.3 Testing and Strength Monitoring

6.3.1 The relationship between 28 compressive strength and 28 day flexural strength shall be determined in a series of preliminary tests undertaken by the contractor which shall be conducted prior to any concrete paving works being undertaken.

6.3.2 The relationship shall be established at each of at least three water:cement ratios namely 0.48, 0.53 and 0.58.

6.3.3 In determining the relationship between compressive strength and flexural strength, the tests shall be based on not less than six compressive-strength specimens and twelve flexural-strength specimens for each water:cement ratio using the aggregates and mix proportions proposed for the works. The results of compressive strength vs flexural strength will be plotted on a graph to determine the relationship.

6.3.4 In addition to the preliminary testing, the relationship between compressive and flexural strength shall be monitored by confirmatory tests done from time to time at the discretion of the *Supervisor*. For this purpose, samples of 6 beams and 3 cubes shall be manufactured from the same batch of concrete and tested for flexural tensile and compressive strengths respectively. If the test results vary from those obtained from the preliminary tests, the specified compressive strength shall be adjusted accordingly.

6.4 General Requirements in Respect of Placing and Compacting Concrete

6.4.1 The provisions of sections Chapters 6 and 7 of COTO Standard Specification for Road and Bridge Works for South African Road Authorities' shall apply for the placing and compacting of concrete for pavements.



7.0 ADDITIONAL REQUIREMENTS FOR SLIP FORMING/SLIDING FOR CAISSON WALLS

7.1 Formwork

7.1.1 The provisions relating to sliding formwork in SANS 2001-CC1 section 4.3.2.2 shall apply. In addition, the construction requirements listed in Chapter 3 of ACI 313-97 – Standard Practices for Design and Construction of Concrete Silos and Stacking Tubes shall also apply.

7.2 Quality of Concrete

7.2.1 The sliding operation shall be undertaken in strict accordance with the provisions of SANS 2001-CC1 Section 4.7.21.

8.0 ADDITIONAL REQUIREMENTS FOR REAR CRANE RAIL PILES

8.1.1 The material requirements for cast-in-place displacement piles in BS EN 12699:2015 shall apply.

8.1.2 The additional requirements for the conformity of concrete for cast-in-place displacement piles in BS EN 206:2013 Annexure D shall apply.

9.0 COMPLIANCE WITH REQUIREMENTS

9.1 Testing

9.1.1 General

9.1.1.1 Concrete test results obtained from a ready-mix production facility, as part of its quality control system, shall not be used.

9.1.1.2 The *Contractor* shall provide an onsite concrete testing facility at the caisson manufacturing site which shall be capable of testing cubes in accordance with SANS 5861-3.

9.1.1.3 Where required the 2-point loading method of the flexural strength tests shall be undertaken in accordance with SANS 5864.

9.1.1.4 The *Contractor* shall keep on the site, and make available to the *Supervisor* on request, full details of the section of concrete to which any particular test cube is related. All test cubes shall be adequately marked for identification.

9.1.1.5 The *Contractor* shall prepare and test at his own expense any additional concrete cubes where he requires to demonstrate to the *Supervisor* that a concrete element has achieved a particular compressive strength after a period other than those specified for routine tests. Such cubes shall be cured under the same conditions as the related element.

9.1.1.6 Records shall be kept by the *Contractor* of the positions in the *works* of all batches of concrete, of their grade, and of all tests, cores and other specimens taken from them. Copies of records shall be supplied to the *Supervisor* as soon as results are available and on a regular basis to a schedule acceptable to the *Supervisor*.

9.1.2 Acceptance of strength concrete

9.1.2.1 The test results may be assessed statistically in accordance with clause 5.1.2.3 of SANS 2001-CC1.



9.1.3 Frequency of sampling

- 9.1.3.1 Frequency of sampling and testing shall be as specified in SANS 2001-CC1 Section 5.13, subject to the testing of a minimum of 3 sets of samples per day from each grade of concrete placed in each independent structure if the concrete quantity from which these samples were taken exceeds 40 m³, and the testing of a minimum of 2 sets of samples per day when such quantity is equal to or less than 40 m³.

9.1.4 Beam tests for SFRC

- 9.1.4.1 Beam tests for SFRC are detailed in Section 5.4.

9.2 Tolerances

- 9.2.1 Deviations shall be within the limits listed in Table 11 of SANS 2001-CC1 for Degree of Accuracy II, unless stated otherwise on drawings or elsewhere in the Works Information.
- 9.2.2 The *Contractor* shall ensure that cumulative tolerances meet with tolerance requirements as defined within this specification.