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7 CONCRETE STRUCTURES

7.1 BRIDGE SPECIFICATION

7.1.1 General Principles

- 1 This section shall be applied for the structural design of temporary and permanent structures of all kind of bridges related to the project, including all bridge substructures such as piers and their foundations, abutments, culverts etc.
- 2 Bridges and other similar structures shall be designed in accordance with the following standards:
 - (a) QCS;
 - (b) Euronorms (EN);
 - (c) EN 1337 Structural bearings.

7.1.2 Design Principles

- 1 The design of bridges and their foundations shall include, but not be limited to, the following:
 - (a) The selection of the structural system for the bridge structure, the piers and foundations;
 - (b) Aesthetics;
 - (c) Clearances;
 - (d) Evacuation and emergency access;
 - (e) Accidental impact from roads;
 - (f) Footbridges-environment within e.g. temperature control, lighting, appearance;
 - (g) Method of bridge construction, including Temporary Works and construction sequence;
 - (h) Ground/structure interaction, including the effects of Temporary Works;
 - (i) Dynamic, seismic loads and displacements;
 - (j) Deflection and rotation of bridge structures;
 - (k) Ground pressure (including swelling), shear force and bending distribution on structural members during construction and in the long-term;
 - (l) Short and long-term ground and groundwater response;
 - (m) Other changes in static loads such as excavation, surcharge, live loads, traffic loadings and others;
 - (n) The variation in ground conditions along the alignment;
 - (o) All dewatering and groundwater cut-off systems required to maintain dry and stable conditions within all excavations required for these Works;
 - (p) The magnitude of ground and existing building structures settlements, movements, distortions and changes in loading conditions of existing building structures expected as a result of the Works and how these shall be mitigated;
 - (q) The presence of existing building structures;
 - (r) Maintenance of traffic flows along roads including access to adjoining properties and roads;
 - (s) Control of heave, swell, piping and instability of the excavations related to the Works (e.g. excavations required for bridge foundations);

- (t) The effects of vibration so as to minimise disturbance to existing building structures; and
 - (u) Effects caused by creep and shrinkage of concrete and the resulting effects (including secondary effects). These effects shall be regarded as permanent loads.
- 2 Vertical clearance to roads shall be in accordance with the relevant local regulations; the minimum vertical clearance to existing and planned roads shall be 6.50 m.
- 3 Decks end rotations
- (a) Vertical end rotation angle of the decks caused by live load, temperature gradient, creep and shrinkage shall be limited to $\Theta = 0.002$ rad at abutments and $\Theta_1 + \Theta_2 = 0.003$ rad between two consecutive decks, refer to figure 7.1.
 - (b) Horizontal end rotation of the decks caused by impact, wind, centrifugal force (if any), hunting force, and effect of transverse temperature gradient across the deck shall be limited to 0.0035 rad. Horizontal deformation includes the deformation of bridge deck and substructure, refer to figure 7.1.

Figure 7.1

Vertical end rotation angle of the decks

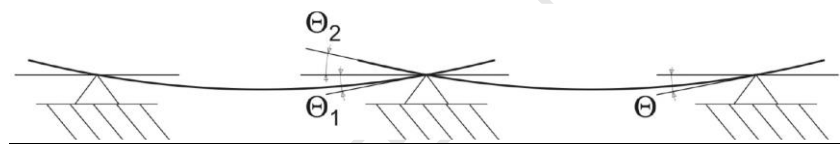
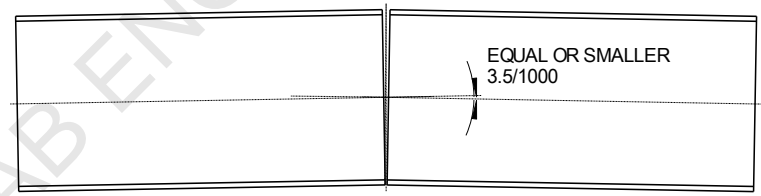


Figure 7.2

Horizontal end rotation angle of the decks



7.1.3 Deck displacements

- 1 Cyclic movements between adjacent span ends (or expansion joints) shall be limited to ± 3 mm vertically and ± 2 mm horizontally (laterally and longitudinally) at the running rail centre line;
- 2 Under braking and traction forces the relative displacement of the individual bridge deck under normal (non-seismic) conditions shall not be more than 5 mm in longitudinal direction. This requirement can be eased if a detailed rail structure interaction calculation demonstrate that the allowable rail stress is within the limits given in UIC 774-3;
- 3 Under seismic actions the deck shall be designed to satisfy the fundamental requirements of EN 1998, including no-collapse and damage minimisation requirements; and
- 4 Under seismic actions (including temperature creep and shrinkage effects) the gap between adjacent decks shall be wide enough to prevent contact of adjacent decks.

7.1.4 Vibration

- 1 The limits of vertical and horizontal vibration shall be as stated in EN 1991.

7.1.5 Fatigue

- 1 Fatigue calculations shall be in accordance with the requirements of EN 1991.

7.1.6 Collision load on piers or decks

- 1 Vehicular collision against the pier shall be considered as per EN 1991.
- 2 Vehicular collision against the deck shall be considered as per EN 1991.

7.1.7 Temporary Works

- 1 In general, Temporary Works shall be designed in accordance with the same design standards as the Permanent Works. However, the Temporary Works design may take into account the limited time they are expected to function. The calculations and drawings shall make clear where provision for limited duration has been allowed for, particularly where this may have a substantial influence on the stability of the Temporary Works.
- 2 The design of Temporary Works shall take into account of all the applied external forces and imposed structural deformations.

7.1.8 Foundations

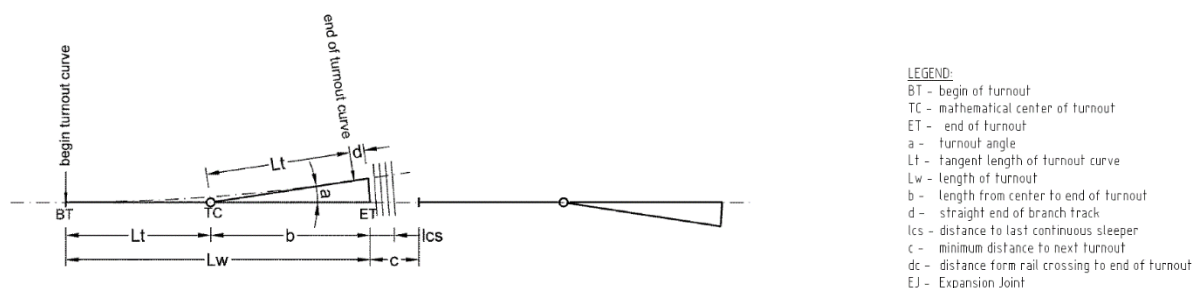
- 1 The top of the foundation surface or pile cap shall be kept at least 1.0 m below the road or ground level.

7.1.9 Turnout on Elevated Sections

- 1 Turnouts shall not be placed over expansion joints between adjacent decks of the viaduct. The following minimum distances shall be kept:
 - (a) Expansion joint to begin of turnout (BT) 2.0 m; and
 - (b) End of turnout (ET) to expansion joint 0.6 m.

Figure 7.3

Turnout



7.1.10 Safety Railing

- 1 Safety railing shall be provided at all locations where the level difference is more than 1.0 m, unless specified in other regulations.
- 2 Safety railing shall have a minimum height of 1.10 m above finish floor level.

7.1.11 Privacy Screening

- 1 Privacy screening shall be provided at certain locations. The Contractor shall coordinate the needs for privacy screening with the relevant authorities.

7.1.12 Noise Barriers

- 1 Noise barriers shall be provided at certain locations. The Contractor shall coordinate the needs for noise barriers with the relevant authorities.

7.1.13 References

- 1 Related Sections are as follows:-

Section 1	General
Section 4	Foundations and Retaining Structures
Section 5	Concrete
Section 14	Roofing
Section 15	Insulation of Buildings

- 2 The following standards are approved and/ or referred to in this Section:

BS 4483	.....Steel fabric for the reinforcement of concrete. Specification
BS 4486	.....Specification for hot rolled and hot rolled and processed high tensile alloy steel bars for the prestressing of concrete
BS 5896	.....High tensile steel wire and strand for the prestressing of concrete. Specification
BS 7973-1	.....Spacers and chairs for steel reinforcement and their specification - Product performance requirements
BS 7973-2	.....Spacers and chairs for steel reinforcement and their specification - Fixing and application of spacers and chairs and tying of reinforcement
BS 8102	.....Protection of below ground structures against water ingress. Code of practice
EN 197	.....Cement
EN 206	.....Concrete - Specification, performance, production and conformity
EN 450	.....Fly ash for concrete
EN 480	.....Admixtures for concrete, mortar and grout - Test methods –
EN 934	.....Admixtures for concrete, mortar and grout
EN 1008	.....Mixing water for concrete - Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete
EN 1337	.....Structural Bearings –
EN 1504	.....Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity -
EN 1504-5	.....Products and systems for the protection and repair of concrete structures - Definitions, requirements, quality control and evaluation of conformity - Part 5: Concrete injection
EN 1990	.....Eurocode - Basis of structural and geotechnical design
EN 1991	.....Eurocode 1: Actions on structures:

EN 1992	Eurocode 2: Design of concrete structures:
EN 1992-1-1	Eurocode 2 - Design of concrete structures - Part 1-1: General rules and rules for buildings, bridges and civil engineering structures
EN 1993	Eurocode 3: Design of steel structures:
EN 1994	Eurocode 4: Design of composite steel and concrete structures;
EN 1997	Eurocode 7 - Geotechnical design:
EN 1998	Eurocode 8: Design of structures for earthquake resistance:
EN 10080	Steel for the reinforcement of concrete - Weldable reinforcing steel – General; (BS 4449 Steel for the reinforcement of concrete. Weldable reinforcing steel. Bar, coil and decoiled product. Specification)
EN 10088	Stainless steels-
EN 12350	Testing Fresh Concrete
EN 12390	Testing Hardened Concrete
EN 12504	Testing concrete in structures -
EN 12504-1	Testing concrete in structures - Part 1: Cored specimens - Taking, examining and testing in compression
EN 12620	Aggregates for concrete
EN 13263	Silica fume for concrete
EN 13391	Mechanical tests for post-tensioning systems
EN 13670	Execution of concrete structures
EN 14487-1	Sprayed concrete - Part 1: Definitions, specifications and conformity
EN 14487-2	Sprayed concrete - Part 2: Execution
EN 14488	Testing sprayed concrete -
EN 14889-1	Fibres for concrete - Part 1: Steel fibres - Definitions, specifications and conformity
EN 14889-2	Fibres for concrete - Part 2: Polymer fibres - Definitions, specifications and conformity
EN 15167	Ground granulated blast furnace slag for use in concrete, mortar and grout
ISO 1460	Metallic coatings — Hot dip galvanized coatings on ferrous materials — Gravimetric determination of the mass per unit area
ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles — Specifications and test methods
ISO 1920	Testing of concrete
ISO 3766	Construction drawings — Simplified representation of concrete reinforcement
ISO 6934	Steel for the prestressing of concrete
ISO 6935-3	Steel for the reinforcement of concrete — Part 3: Welded fabric
ISO 15630	Steel for the reinforcement and prestressing of concrete - Test methods

The Concrete Society CS163. Guide to the design of concrete structures in the Arabian Peninsula.

The European Guidelines for Self-Compacting Concrete Specification, Production and Use

UIC - International union of railways Standards;
Recommendations for calculations

UIC 774-3 Track - bridge Interaction.

7.2 BUILDING DESIGN STRUCTURAL SPECIFICATION

7.2.1 General Principles

- 1 This section shall be applied for the structural design of temporary and permanent structures of buildings related to the project, which are not already covered under sections above.
- 2 The design shall be in accordance with:
 - (a) Qatar General Organization for Standardization
 - (b) QCS;
 - (c) Euronorms (EN).

7.2.2 Design Principles

- 1 The design of buildings and their foundations shall include, but not be limited to, the following:
 - (a) The selection of the structural system;
 - (b) Aesthetics;
 - (c) Clearances;
 - (d) Evacuation and emergency access;
 - (e) Method of building construction, including Temporary Works and construction sequence;
 - (f) Ground/structure interaction, including the effects of Temporary Works;
 - (g) Dynamic, seismic loads and displacements;
 - (h) Ground pressure (including swelling), shear force and bending distribution on structural members during construction and in the long-term;
 - (i) Short and long-term ground and groundwater response;
 - (j) Other changes in static loads such as excavation, surcharge, live loads, traffic loadings and others;
 - (k) The effects of vibration so as to minimise disturbance to existing building structures; and
 - (l) Effects caused by creep and shrinkage of concrete and the resulting effects (including secondary effects). These effects shall be regarded as permanent loads.

7.2.3 Civil and structural design statement

- 1 Prior to the design of the buildings, the Contractor shall submit a civil and structural design statement which shall include:
 - (a) All relevant applicable codes, regulations and specifications;
 - (b) Design assumptions;
 - (c) Loads and load combinations;
 - (d) Applicable safety factors;
 - (e) Deformation and tolerances;
 - (f) The proposed structural and foundation system;
 - (g) The proposed construction methodology; and
 - (h) Materials.

- 2 The civil and structural design statement shall be submitted to the Engineer for a SONO.

7.3 STRUCTURAL CONCRETE

7.3.1 General Requirements

1 Materials and Production

- (a) All concrete aggregates, additives aggregates, spacers, precast elements and other concrete related construction materials shall be produced and delivered with a certification and CE-mark.
- (b) Detailed specifications for all types of concrete shall be provided to the Engineer for SONO.
- (c) Special provisions shall be made for pre-stressed concrete elements with respect to aggregate gradation, spacers for tendon placement and concrete quality near anchor locations, as specified in the design.

2 Concrete

- (a) Testing of concrete shall be performed in a laboratory conforming to the requirements in EN 206 and Section 5; (EN 12350 Testing Fresh Concrete; EN 12390 Testing hardened concrete; ISO 1920 Testing of concrete)

3 Cement:

- (a) All cement shall comply with the requirements of EN 197.

4 Fly Ash:

- (a) Fly ash shall comply with the requirements of EN 450.

5 Ground Granulated Blast furnace Slag (GGBFS):

- (a) GGBFS shall comply with the requirements of EN 15167.

6 Silica Fume:

- (a) Silica fume for concrete shall comply with EN 13263.

7 Aggregates: Fine Aggregate

- (a) Fine aggregates shall be natural or crushed rock sand in compliance with EN 12620.
- (b) In case of change of the source of supply, the Engineer shall be notified in advance.

8 Aggregates: Coarse Aggregates

- (a) Coarse aggregates shall be crushed aggregate from an approved natural source in compliance with EN 12620.
- (b) In case of change of the source of supply, the Engineer shall be notified in advance.

9 Water:

- (a) Water for concrete mixing, ice, washing and cooling of aggregates as well as curing shall comply with EN 1008 and Section 5.

10 Additives: Admixtures

- (a) The admixtures shall conform to the general and specific requirements of EN 934-2, EN 934-4, EN 934-6 and Section 5.
- (b) Admixtures shall be delivered to the concrete production site in original sealed packing, clearly marked and labelled to EN 934-2.

- 11 Concrete Mix Design
- (a) All concrete mix designs shall be submitted to the Engineer for SONO.
 - (b) The Contractor shall calculate the temperatures of the freshly produced concrete, based on the input temperatures of the components of the mix design.
 - (c) It shall be documented by an automatic recording system that the batched quantities for each batch are in accordance with the mix design.
- 12 Fresh Concrete Properties
- (a) The testing shall comply with EN 206 and Section 5.
 - (b) Freshly mixed concrete shall be sampled in accordance with EN 12350-1.
 - (c) Tests shall be in accordance with the following standards:
 - (i) Slump Test: EN 12350-2
 - (ii) Vebe Test: EN 12350-3
 - (iii) Compaction test: EN 12350-4
 - (iv) Flow Test: EN 12350-5
- 13 Hardening and Hardened Concrete Properties
- (a) The testing shall comply with EN 206 and Section 5.
- 14 Curing
- (a) Curing and protection shall comply with the requirements of QCS.
- 15 Execution of Repair Works
- (a) Execution of crack injection using epoxy or acrylic shall be in accordance with the manufacturer's instructions and EN 1504-5.

7.4 REINFORCEMENT

7.4.1 General

- 1 This specification sets out the minimum standards, including but not limited to materials and workmanship as follows:
- (a) the steel shall be produced and classified in accordance with EN 10080;
 - (b) spacers shall be in accordance with BS 7973-1, Product performance requirements and BS 7973-2;
 - (c) binding wire shall not stain the concrete surface;
 - (d) wire mesh shall be constructed of transversal and longitudinal wires using B500A quality steel according to ELOT 1421-2; ISO 6935-3 or BS 4483.
 - (e) mechanical couplers may be used;
 - (f) galvanised reinforcement shall be hot dip galvanised, after cutting to length and bending;
 - (g) galvanising shall satisfy the requirements according to standards ISO 1460 and ISO 1461;
 - (h) stainless steel reinforcement shall comply according to EN 10088.

7.4.2 Execution – Wire Mesh

- 1 Wire mesh shall be installed in Sprayed Concrete Lining (SCL) tunnels embedded in shotcrete.
- 2 In cases where, during the installation of the wire mesh its extension is required, the overlapping of the mesh shall, at a minimum be as follows:
 - (a) At least equal to 300 mm, concerning extension of the main reinforcement (strength) of the mesh; and
 - (b) At least equal to 150 mm, concerning extension of the secondary reinforcement (distribution) of the wire mesh.
- 3 The overlapping edges shall be tightly fixed together through wires, or held by means of standard couplers.

7.4.3 Execution – Bar Bending Schedules

- 1 The minimum lap lengths and effective anchorage lengths for bars under stress shall be full tension lap lengths in accordance with EN 1992-1-1.

7.4.4 Execution – Bending

- 1 Bars shall be bent in accordance with the provisions of standard EN 1992-1-1.
- 2 Any reinforcement showing signs of damage shall be rejected and removed from the Site.
- 3 The reinforcement shall be accurately cut and bent to the form shown on the bending schedules in accordance with standard ISO 3766.

7.4.5 Execution – Fixing

- 1 The steel for stainless steel tying wire shall be grade 1.4404 in accordance with standard EN 10088-1.

7.4.6 Execution – Reinforcing Steel Testing

- 1 The methods of testing and the methods of attestation of conformity shall be as defined in standard EN 10080.

7.4.7 Steel Fibres

- 1 The steel fibres shall comply with standard EN 14889-1.
- 2 The minimum properties of the steel fibres shall be:
 - (a) the steel fibres shall be made of low carbon, cold drawn wire (EN 14889: Group 1), have a circular cross section with hooked ends.
 - (b) Tensile strength of the wire shall be minimum 1100 N/mm².
 - (c) Nominal length of the steel fibres shall be between 40 and 60 mm.
 - (d) Aspect ratio (L/D) shall be between 50 and 70.
 - (e) The steel fibres shall be distributed evenly within the concrete mix.

7.4.8 Glass Fibre Reinforced Plastics (GRP)

- 1 The design of GRP soft eye structures shall be produced and classified in accordance with standard QCS – Section 8, Part 7.
- 2 The design of GRP soft eye structures shall be in accordance with standard EN 1992-1-1.

7.5 PRESTRESSED CONCRETE

7.5.1 General Requirements

- 1 This document contains minimum requirements for pre-stressed and post-tensioned concrete.
- 2 Detailed records of the stressing and grouting including steel tests and materials certificates, shall be available for inspection at all times.
- 3 The minimum quality requirements for materials and workmanship shall be determined by the following documents listed in order of precedence:
 - (a) Qatar Construction Specifications (QCS)
 - (b) EN 1992, EN 13670 Pre-stressing Tendons .

7.5.2 Materials

- 1 Steel wire shall comply with BS 5896.
- 2 Cold worked high tensile alloy steel bars for pre-stressing shall comply with the requirements of BS 4486.

7.5.3 Handling and Storage

- 1 All pre-stressing tendons shall be stored in such a way as to avoid damage of any kind.
- 2 Each cable shall be tagged with its number from which the coil numbers of the steel used can be identified.

7.5.4 Surface condition

- 1 Stressing tendons anchorages, blocking devices and internal and external surfaces of ducts shall be clean and free from pitting, loose rust, loose scale and chloride contamination at the time of incorporation during the Work.
- 2 Slight rusting of the steel, which can be removed by moderate rubbing, is acceptable, but the surface shall not show signs of pitting. Tendons showing pitting are not to be used and shall be removed from Site.

7.5.5 Straightness

- 1 Pre-stressing bars shall be straight.
- 2 Bars bent in the threaded portion shall be rejected.

7.5.6 Post-tensioning

- 1 Anchorages and deflected Tendons
 - (a) Anchorages shall be tested in accordance with the requirements of EN 13391.
 - (b) Proprietary anchorages shall be handled and used strictly in accordance with the manufacturer's instructions and recommendations.
- 2 Tensioning procedure
 - (a) Full and detailed records shall be kept of all tensioning operations, including the measured extensions, pressure-gauge or load-cell readings, and the amount of draw-in at each anchorage. These records shall be available for inspection at all times.

7.5.7 Pre-stressing Tendons

- 1 Protection and Bond
 - (a) The exposed tendons at the anchorages and the anchorages shall be protected from both mechanical damage and corrosion.

2 Ducts for bonded tendons

- (a) Ducts for longitudinal, transverse or vertical tendons embedded into the concrete shall be of flexible, semi-rigid, or rigid galvanized, ferrous metal capable of withstanding concrete pressures without deforming or permitting the entrance of cement paste during casting of the member.
- (b) Ducts shall retain their shape and be capable of transferring bond stresses.

7.5.8 Grouting of Pre-stressing Tendons

1 General Information

- (a) All ducts shall be thoroughly cleaned and all anchorages shall be sealed before grouting.

2 Ducts

- (a) All ducts shall be thoroughly cleaned before grouting.
- (b) All surplus water shall be removed.

3 Grouting Equipment

- (a) The mixing equipment shall produce grout of homogeneous consistency and shall be capable of providing a continuous supply to the injection equipment.

4 Injecting Grout

- (a) The method of injecting grout shall ensure complete filling of the ducts and complete surrounding of the steel.
- (b) The Contractor shall keep full records of grouting, including the date each duct was grouted, the proportion of the grout and any admixtures used, the pressure, details of any interruptions and topping up required. These records shall be available for inspection at all times.

7.5.9 Preparation for Casting

1 General information

- (a) Pre-stressing steel for post-tensioning which is installed in members prior to placing and curing of the concrete, shall be continuously protected against rust or other corrosion, until grouted.

7.6 SHOTCRETE

7.6.1 General

- 1 This specification concerns the provision of materials and workmanship for the production and application of shotcrete.

7.6.2 Mix Reports

- 1 Reports of each shotcrete mix shall be produced and copies made available on Site for inspection by the Engineer.

7.6.3 Production

1 Cement

- (a) Cement used in shotcrete laying and maintenance works shall meet the requirements of EN 197-1. The minimum required content in Type CEM I 42,5 cement shall be 400 kg/m³.

2 Aggregates

- (a) Aggregates used in shotcrete application and maintenance works shall be either natural or crushed and shall comply with EN 12620.

3 Admixtures

- (a) All admixtures used in shotcrete laying and maintenance works shall comply with EN 934-2, EN 934-5 and EN 934-6.

4 Reinforcement

- (a) if steel fibres are used, the minimum quantity shall not be less than 30 kg/m³;
- (b) steel fibres shall comply with the requirements of Annex B of EN 14487-1;
- (c) any fibres for shotcrete reinforcement shall be sufficiently small to ensure their uniform spreading in the mass of the shotcrete and avoid the formation of lumps.

5 Application of fibre reinforced shotcrete

- (a) Fibre reinforced shotcrete shall be applied in accordance with EN 14487-1, EN 14889-1 and EN 14889-2.

6 Curing of Shotcrete

- (a) The shotcrete curing method shall comply with EN 14487-2.

7.6.4 Quality control

1 In situ checks

- (a) The thickness of any applied shotcrete shall be verified.

2 Shotcrete quality tests

- (a) For each shotcrete mix design, at least three (3) test panels for performing tests shall be prepared, as described below:
 - (i) test panels as well as the Contractor's sampling method shall be in accordance with EN 14488-1;
 - (ii) one (1) test panel shall be taken for each day of shotcreting;
 - (iii) upon initial setting, test panels shall be transferred to the laboratory;
 - (iv) the number of cores taken from each test panel, their dimensions and compliance control shall be in accordance with EN 14487-1;
 - (v) the strength of shotcrete panels shall be checked in accordance with EN 14488-2. The required cylinder strength for 24 hours shall be class J2, as per paragraph 4.3 of EN 14487-1 and minimum value of 10 MPa;
 - (vi) testing of shotcrete already applied shall be performed in accordance with EN 12504-1; and
 - (vii) if test results for shotcrete already applied fail, immediate measures shall be taken to preserve the safety and stability of the Works, and the Engineer shall be notified.

7.7 FORMWORK

7.7.1 General Requirements

- 1 This section includes the design, production and installation of formwork in accordance with QCS.
- 2 All material for formwork shall be of a quality capable of providing a dense concrete surface.
- 3 Drawings and calculations shall be sufficiently detailed to document adequate strength, rigidity, and stability to meet all load combinations during the erection of the Permanent Work.

7.7.2 Formed finishes

- 1 Formed surfaces shall be according to QCS.

7.7.3 Unformed finishes

- 1 Unformed surfaces shall be according to QCS.

7.8 WATERPROOFING

7.8.1 General

- 1 This section refers to the supply and installation of the waterproofing systems in concrete structures.
- 2 The purpose of the waterproofing systems is to prevent leakage of groundwater into the structures and to protect the concrete against deleterious chemical influences.
- 3 All waterproofing works shall be executed in accordance with BS 8102.
- 4 All the materials to be used for waterproofing shall be compatible with each other, as well as with any bordering materials such as concrete. Any harmful chemical influences shall be prevented.
- 5 The waterproofing system used shall be suitable for the Works and the local conditions of ground and groundwater. Any expected movement of the structural elements caused by shrinkage, temperature changes and settlements, should not result in the waterproofing system losing its waterproofing properties.
- 6 All waterproofing systems shall be installed and tested in accordance with the manufacturer's instructions or recommendations. Testing shall be undertaken as necessary to ensure satisfactory functioning of the system at each stage of the installation. Defective waterproofing systems shall be repaired in accordance with the manufacturer's instructions or replaced.
- 7 The waterproofing system shall be applied only after effectively sealing of all cracks on exposed surfaces of the external structural members as per the manufacturer's instructions or recommendations.

7.8.2 Waterproofing classes

- 1 Waterproofing classes are defined in the following table:

Table 7.1
Waterproofing classes

Waterproofing Class	Definition for impermeability	Characteristic of the waterproofed inner surface General
1	Completely dry	The inner surface shall not show any moisture areas. Acceptable amount of water: no water.
2	Largely dry	On the inner surface, weak moisture penetration shall only appear on max. 10% of each structure's section surface (visible as a dark colour change on the concrete surface). On dry hands contacting weak moisture areas, no evident marks of water shall be visible afterwards. Disposed blotting paper or absorbent newsprint shall not change in colour due to moisture absorption. Acceptable amount of water: any quantity less than the acceptable amount of waterproofing class 3.
3	Slightly wet	On the inner surface, weak moisture penetration shall only appear on 10% of each structure's section surface (visible as a dark colour change on the concrete surface). Acceptable amount of water: general 0.02 litre/m ² /d.

7.8.3 Waterproofing for Cast in Situ Concrete

1 Watertightness

- (a) Cast in situ concrete linings for tunnels, cross passages and shafts shall be waterproofing class 1.
- (b) Cast in situ concrete for underground plant rooms shall be waterproofing class 1.

7.8.4 Waterproofing for Precast Concrete Segmental Tunnel Linings

1 Watertightness

- (a) Precast concrete segmental linings shall be of waterproofing class 1

7.8.5 Waterproofing for Cut and Cover Structures and Open Troughs

1 Watertightness

- (a) Cast in situ concrete for cut-and-cover and open troughs shall be waterproofing class 1.

END OF PART