# GENERAL MATERIALS AND WORKMANSHIP SPECIFICATION

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16.1 DEFINITIONS & ABBREVIATIONS

16.1.1 Definitions

Words and expressions to which meanings have been assigned in the General Conditions and General Specification, shall have the same meanings in this volume.

16.1.2 Abbreviations

Abbreviations in this volume shall have the following meanings:

- AAR: Alkali-Aggregate Reaction
- ACI: American Concrete Institution
- APHA: American Public Health Authority
- ASSHTO: American Association of State Highway and Transportation Officials
- ASTM: American Society for Testing and Material
- BS: British Standard
- CAPWAP: CASE Pile Wave Analysis Program
- CI: Chloride Ion
- CS: Construction Standard
- C&D: Construction and Demolition
- GIFW: Ground Investigation Field Work
- HKQAA: Hong Kong Quality Assurance Agency
- HOKLAS: Hong Kong Laboratory Accreditation Scheme
- HSFG: High Strength Friction Grip
- IRHD: International Rubber Hardness Degree
- OPC: Ordinary Portland Cement
- PFA: Pulverised Fuel Ash
- PNAP: Practice Notes for Authorized Persons and Registered Structural Engineers
- PPFAC: Portland Pulverised Fuel Ash Cement
- P.T.F.E.: Polytetrafluoroethylene
- PVC: Polyvinyl Chloride
- QSPSC: Quality Scheme for the Production and Supply of Concrete
- RHPC: Rapid Hardening Portland Cement
- RSC: Registered Specialist Contractor
- SIS: Swedish Standard
- SRPC: Sulphate Resisting Portland Cement
16.2 RELEVANT CODES AND STANDARDS

The Standards and Codes of Practice specified in this Section are listed below for information only. The Contractor shall comply with the edition of the Standard or Code of Practice listed in the text when stated, or the latest edition when no edition is listed.

16.2.1 American Standards

ASTM A775 Standard specification for epoxy-coated reinforcing steel bars
ASTM A775M Standard specification for epoxy-coated reinforcing steel bars
ASTM C-494 Type C Standard specification for chemical admixtures for concrete-Type C – Accelerating admixtures
ASTM C939-94 Standard test method for flow of grout for preplaced-aggregate concrete (flow cone method)
ASTM D1293-78 Standard test methods for pH of water
ASTM D512-81, Method B Standard test methods for chloride ion in water
ASTM D516-80, Method A Standard test method for sulfate ion in water

16.2.2 British Standards

BS 4-1: 1993 Structural steel sections. Specification for hot-rolled sections
BS 12: 1996 Specification for Portland cement
BS 29:1987 Specification for carbon steel forgings above 150 mm ruling section
BS 639: 1986 Specification for covered carbon and carbon manganese steel electrodes for manual metal-arc welding
BS 729:1986 Specification for hot dip galvanized coatings on iron and steel articles
BS 812:Part 4:1976 Sampling and testing of mineral aggregates, sands and fillers
BS 812-103: 1985 Method for determination of particle size distribution
BS 812-111:1990 Testing aggregates. Methods for determination of ten per cent fines value (TFV)
BS 882:1992 Specification for aggregates from natural sources for concrete
| BS 903-A18: 1998 | Physical testing of rubber. Determination of equilibrium water vapour absorption |
| BS 903-A2: 2002 | Physical testing of rubber. Method for determination of tensile stress-strain properties |
| BS 903-A5:1997 | Physical testing of rubber. Determination of tension set at normal and high temperatures |
| BS 903-A26:1995 | Physical testing of rubber. Method for determination of hardness (hardness between 10 IRHD and 100 IRHD) |
| BS 970-1:1996 | Specification for wrought steels for mechanical and allied engineering purposes. General inspection and testing procedures and specific requirements for carbon, carbon manganese, alloy and stainless steels |
| BS 1014:1986 | Specification for pigments for Portland cement and Portland cement products |
| BS 1154:1992 | Specification for natural rubber compounds |
| BS 1305:1974 | Specification for batch type concrete mixers |
| BS 1449-1: 1983 | Carbon and carbon-manganese plate, sheet and strip |
| BS 1470:1987 | Specification for wrought aluminium and aluminium alloys for general engineering purposes: plate, sheet and strip |
| BS 1473:1972 | Specification for wrought aluminium and aluminium alloys for general engineering purposes - rivet, bolt and screw stock |
| BS 1474:1987 | Specification for wrought aluminium and aluminium alloys for general engineering purposes: bars, extruded round tubes and sections |
| BS 1490:1988 | Specification for aluminium and aluminium alloy ingots and castings for general engineering purposes |
| BS 1610: 1985 | Materials testing machines and force verification equipment |
| BS 1615:1987 | Method for specifying anodic oxidation coatings on aluminium and its alloys |
| BS 1706:1990 | Method for specifying electroplated coatings of zinc and cadmium on iron and steel |
| BS 2451:1988 | Specification for chilled iron shot and grit |
| BS 2499: 1992 | Hot-applied joint sealant systems for concrete pavements |
| BS 2569:Part 1:1988 | Specification for sprayed metal coatings. Protection of iron and steel by aluminium and zinc against atmospheric corrosion |
BS 2600  Radiographic examination of fusion welded butt joints in steel
BS 2648:2000  Performance requirements for electrically-heated laboratory drying ovens
BS 2752:1990  Specification for chloroprene rubber compounds
BS 2782-3: 2002  Mechanical properties
BS 2782-4: 1983  Chemical properties
BS 2782-6: 1991  Dimensional properties
BS 2846:Part 3:1975  Determination of a statistical tolerance interval
BS 2846:Part 4:1976  Techniques of estimation and tests relating to means and variances
BS 2910:1986  Methods for radiographic examination of fusion welded circumferential butt joints in steel pipes
BS 2989:1992  Specification for continuously hot-dip zinc coated and iron-zinc alloy coated steel flat products: tolerances on dimensions and shape
BS 3019:Part 2:1960  Austenitic stainless and heat resisting steels
BS 3100:2001  Specification for steel castings for general engineering purposes
BS 3148:1980  Methods of test for water for making concrete (including notes on the suitability of the water)
BS 3410:1961  Specification for metal washers for general engineering purposes
BS 3416: 2000  Specification for bitumen-based coatings for cold application, suitable for use in contact with potable water
BS 3571:Part1:1985  Specification for MIG welding of aluminium and aluminium alloys
BS 3601:1993  Specification for carbon steel pipes and tubes with specified room temperature properties for pressure purposes
BS 3690:Part1:1989  Specification for bitumen for roads and other paved areas

BS 3923-2:1972  Methods for ultrasonic examination of welds. Automatic examination of fusion welded butt joints in ferritic steels

BS 4027:1996  Specification for sulfate-resisting Portland cement

BS 4147:1987  Specification for bitumen-based hot-applied coating materials for protecting iron and steel, including suitable primers where required

BS 4168-1:1981  Hexagon socket screws and wrench keys: metric series. Specification for hexagon socket head cap screws

BS 4190:2001  ISO metric black hexagon bolts, screws and nuts. Specification

BS 4232:1967  Specification for surface finish of blast-cleaned steel for painting

BS 4248:1974  Specification for supersulphated cement

BS 4254:1983  Specification for two-part polysulphide-based sealants

BS 4320:1968  Specification for metal washers for general engineering purposes. Metric series

BS 4360:1990  Specification for weldable structural steels


BS 4395-1:1998  Specification for high strength friction grip bolts and associated nuts and washers for structural engineering. General grade

BS 4395-2:1998  Specification for high strength friction grip bolts and associated nuts and washers for structural engineering. Higher grade bolts and nuts and general grade washers

BS 4447:1973  Specification for the performance of prestressing anchorages for post-tensioned construction

BS 4449:1997  Specification for carbon steel bars for the reinforcement of concrete

BS 4461:1997  Specification for cold worked steel bars for the reinforcement of concrete

BS 4466:1989  Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete

BS 4482:1985  Specification for cold reduced steel wire for the reinforcement of concrete

BS 4483:1998  Steel fabric for the reinforcement of concrete

BS 4486:1980  Specification for hot rolled and hot rolled and processed high tensile alloy steel bars for the prestressing of concrete

BS 4550: Methods of testing cement
BS 4550:Part 1:1978: Methods of testing cement. Sampling
BS 4550:Part 2:1970: Methods of testing cement. Chemical tests
BS 4551: 1980: Methods of testing mortars, screeds and plasters
BS 4570:1985: Specification for fusion welding of steel castings
BS 4576-1:1989: Unplasticized polyvinyl chloride (PVC-U) rainwater goods and accessories. Half-round gutters and pipes of circular cross-section
BS 4652:2000: Specification for zinc-rich priming paint (organic media)
BS 4677:2001: Specification for arc welding of austenitic stainless steel pipework for carrying fluids
BS 4848: Hot-rolled structural steel sections
BS 4872-1:1999: Specification for approval testing of welders when welding procedure approval is not required. Fusion welding of steel
BS 4921:1994: Specification for sherardized coatings on iron or steel
BS 4933:1973: Specification for ISO metric black cup and countersunk head bolts and screws with hexagon nuts
BS 5075-1:1982: Concrete admixtures. Specification for accelerating admixtures, retarding admixtures and water reducing admixtures
BS 5075-3:1985: Concrete admixtures. Specification for superplasticizing admixtures
BS 5135:1984: Specification for arc welding of carbon and carbon manganese steels
BS 5328: Concrete
BS 5400-6:1999  Steel, concrete and composite bridges. Specification for materials and workmanship, steel
BS 5490:1977  Specification for classification of degrees of protection provided by enclosures
BS 5493:1977  Code of practice for protective coating of iron and steel structures against corrosion
BS 5531:1988  Code of practice for safety in erecting structural frames
BS 5573:1978  Code of practice for safety precautions in the construction of large diameter boreholes for piling and other purposes
BS 5812  Materials for plain bearings
BS 5896:1980  Specification for high tensile steel wire and strand for the prestressing of concrete
BS 5950-1:1990  Structural use of steelwork in building. Code of practice for design. Rolled and welded sections
BS 5950-2:1990  Structural use of steelwork in building. Specification for materials, fabrication and erection. Rolled and welded sections
BS 5950-3.1:1990: Code of practice for design of simple and continuous composite beams
BS 5950-4:1994:  Code of practice for design of composite slabs with profiled steel sheeting
BS 5950-5:1998  Code of practice for design of cold formed thin gauge sections
BS 5950-6:1995  Code of practice for design of light gauge profiled steel sheeting
BS 5950-7:1990  Structural use of steelwork in building. Specification for materials and workmanship: cold formed sections
BS 5975:1996  Code of practice for falsework
BS 5996:1993  Specification for acceptance levels for internal imperfections in steel plate, strip and wide flats, based on ultrasonic testing
BS 6072:1986  Method for magnetic particle flaw detection
BS 6089:1981  Guide to assessment of concrete strength in existing structures
BS 6105:1981  Specification for corrosion-resistant stainless steel fasteners
BS 6232  Thermal insulation of cavity walls by filling with blown man-made mineral fibre
BS 6323-1:1990  Specification for seamless and welded steel tubes for automobile, mechanical and general engineering purposes. General requirements
BS 6323-8:1990 Specification for seamless and welded steel tubes for automobile, mechanical and general engineering purposes. Specific requirements for longitudinally welded stainless steel tubes

BS 6363:1983 Specification for welded cold formed steel structural hollow sections

BS 6404 Magnetic materials

BS 6443:1984 Method for penetrate flaw detection

BS 6588:1996 Specification for Portland pulverized-fuel ash cements

BS 6780:1986 Specification for through thickness reduction of area of steel plates and wide flats

BS 8004:1986 Code of practice for foundations

BS 8110:1985 Structural use of concrete


BS EN 10025:1993 Hot rolled products of non-alloy structural steels. Technical delivery conditions

16.2.3 Hong Kong Standards and Codes of Practice

CS 1 Testing concrete

CS 2 Carbon steel bars for the reinforcement of concrete

PNAP Practice note for authorized persons and registered structural engineers

PNAP 66 Pile foundations

PNAP 71 Demolition works – Measures for public safety

PNAP 122 Testing of reinforcement for concrete

PNAP 132 Site investigation and ground investigation

PNAP 161 Development in the area numbers 2 & 4 of scheduled areas

PNAP 187 Code of practice for the structural use of concrete 1987

PNAP 214 New contractor registration system and the contractors registration committee

PNAP 242 Quality supervision requirements for foundation works

PNAP 243 Construction and Demolition Waste

Code of practice for site safety supervision

Technical memorandum for site safety

16.2.4 Swedish Standards

SIS 05 59 00 Surface preparation standard for painting steel surfaces
SECTION 17  PILING WORKS

17.1  GENERAL

17.1.1 General Requirements

The works and materials specified below shall comply with the Sections stated, unless otherwise stated in this Section.

(a) Earthworks shall comply with Section 7.

(b) Steel reinforcement shall comply with Section 19.

(c) Concrete shall comply with Section 20.

(d) Materials for grout for piling works shall comply with Section 20.

(e) Grouting for piling works shall comply with Section 21.

(f) Prestressing shall comply with Section 21.

(g) Steelwork shall comply with Section 22.

17.2  DEFINITIONS AND ABBREVIATIONS

17.2.1 Barrette

A barrette is a pile formed by excavation using grabs and chisels through a thixotropic suspension of bentonite or other agent which supports the sides of the shaft as excavation proceeds, and which is concreted in one continuous operation.

17.2.2 Bored Piles

Bored piles are cast-in-situ concrete piles formed by boring or grabbing. Piles with a diameter 600 mm or less are commonly referred to as small diameter piles, while piles with a diameter greater than 600 mm are referred to as large diameter piles.

17.2.3 Minipiles

A minipile is a pile with a diameter of less than 400 mm in which the load bearing element consists of one or more steel reinforcement bars. Permanent steel casing above rockhead level is used to contain the grout.

17.2.4 Rock-Socketted Steel H-piles

A rock socketted steel H-pile is a pile formed by inserting a steel H-pile in a pre-bored hole sunk into Grade III or better rock, with a temporary steel casing above the rock head level and subsequent filling of the holes with cement grout.

17.2.5 Driven Steel H-piles

A driven steel H-pile is a H-section steel pile installed by percussive methods.
17.2.6 Continuous Flight Augur Piles

A continuous flight augur pile is a pile formed by a flight augur and subsequent pressurized injection with cement-sand grout through the augur’s stem as it is being withdrawn.

17.3 RELEVANT CODES AND STANDARDS

17.3.1 Regulations, Codes of Practice, Design and Quality Supervision Guidelines and Site Safety Supervision

Piling works shall comply with the Building (Construction) Regulations of Hong Kong, Practice Notes for Authorised Persons and Registered Structural Engineers (PNAP) and other codes and standards set out below.

17.3.2 Pile Caps

Pile caps shall comply with the Hong Kong Code of Practice for the Structural Use of Concrete in respect of all materials and workmanship for reinforced concrete pile caps and for structural concrete above piles. Where BS 8110 is used, specific requirements as specified in PNAP 187 shall be followed. Editions of BS 8110 other than the 1985 version shall not be used unless otherwise reviewed without objection by the Project Manager.

17.3.3 Safety of Piling Works

Piling works shall comply with the following;

(i) Code of practice for site safety supervision
(ii) Technical memorandum for site safety
(iii) BS 8004: Code of practice for foundations
(iv) BS 5573: Code of practice for safety precautions in the construction of large diameter boreholes for piling and other purposes

17.3.4 Specialist Foundation Contractor

All piling works shall be carried out by a Registered Specialist Contractor (Foundation Works) under the Buildings Ordinance except where exempted in PNAP 214.

17.4 MATERIALS

17.4.1 Steel Piles

(a) Steel bearing piles shall be of a proprietary section reviewed without objection by the Project Manager.

(b) Steel sheet piles shall be of a proprietary section reviewed without objection by the Project Manager.

(c) Steel bearing piles and steel sheet piles shall be manufactured from Grade 50B steel and comply with BS 4360 and BS 5950:Part 2.

(d) Steel pipe piles shall comply with BS 3601 or BS 6232:Parts 1 and 2, except for the requirements of hydraulic pressure tests.

(e) All steel piles shall be free from loose scale and rust.
17.4.2 Pile Shoes

(a) Pile shoes for driven cast-in-place piles shall be manufactured from durable materials capable of withstanding driving stresses without damage. The shoes shall be designed to provide a watertight joint with permanent casings.

(b) Cast steel pile shoes for steel bearing piles shall be manufactured from steel complying with BS 3100, Grade A.

(c) Welded fabricated pile shoes for steel bearing piles shall be manufactured from steel complying with BS 4360, Grade 43A.

17.4.3 Epoxy Paint

Epoxy based paint for epoxy coatings to steel piles shall be a proprietary type reviewed without objection by the Project Manager.

17.4.4 Bituminous Coating Material

Bituminous coating material for steel piles shall be hot-applied filled or unfilled bituminous material complying with BS 4147.

17.4.5 Grout for Piling Works

(a) Grout for piling works shall consist of OPC and water. Sand, PFA and admixtures may be used subject to review without objection by the Project Manager.

(b) The minimum cementitious content of grout shall be 600 kg/m$^3$.

(c) Grout used to fill core holes shall be non-shrink grout and have a minimum characteristic compressive strength of not less than the specified grade strength of the concrete surrounding the core hole.

(d) Grout used to fill minipiles and pre-bored rock socketted steel H-piles shall be non-shrink grout and have a minimum characteristic compressive strength of 30 MPa at 28 days.

(e) Water used in the grout must be clean and fresh with a temperature not exceeding 30°C nor less than 5°C.

(f) The maximum amount of bleeding of grout shall not exceed 2% in the first 3 hours and shall not exceed 4% in total; the water shall be reabsorbed by the grout during the 24 hours after mixing.

(g) Free expansion of grout shall not exceed 10% at the ambient temperature.

(h) The chloride ion content of admixtures for concrete containing embedded metal or for concrete made with SRPC shall not exceed 2% by mass of the admixture or 0.03% by mass of the cementitious content, whichever is less.

(i) The maximum total chloride content of grout, expressed as a percentage relationship between the chloride ion and the cementitious content by mass in the grout, shall not exceed 0.1%.

(j) Admixtures shall be chloride free and comply with BS 5075 and shall be submitted for review without objection by the Project Manager before use.
17.4.6 Reinforcement Connectors

(a) Reinforcement connectors shall be of a proprietary type reviewed without objection by the Project Manager.

(b) Connectors shall be capable of transmitting the total pile load in tension or compression as appropriate.

(c) Connectors for tension joints shall be:
   
   (i) cold swaged or threaded type;

   (ii) capable of developing the full tensile strength of the parent bar; and

   (iii) comprised of high tensile studs and seamless steel tubes fitted with protective plastic caps.

(d) Connectors for compression joints, shall be wedge locking, bolted sleeve type.

17.4.7 Surface Treatment of Steel Piles

(a) Surface preparation and application of protective coatings other than bituminous coatings to steel piles shall be carried out in a fully enclosed well-ventilated workshop.

(b) The method of application of protective coatings to steel piles, the ambient temperature and humidity at the time of application and the time interval between the application of successive coats shall be in accordance with the manufacturer's recommendations. The complete coating shall be applied in and around clutches.

17.4.8 Surface Preparation of Steel Piles

The surfaces of steel piles to which protective coatings will be applied shall be prepared by blast cleaning to either:

(a) second quality of surface finish in accordance with BS 4232; or

(b) Sa21/2 in accordance with Swedish Standard SIS 05 59 00.

17.4.9 Epoxy Coatings to Steel Piles

(a) Epoxy coatings to steel piles shall consist of three coats of epoxy based paint, each coat having a minimum dry film thickness of 75 μm. The first coat shall be applied within two hours of blast cleaning.

(b) The finished surface of epoxy coatings shall be smooth with a dense and uniform texture and shall be free from sharp protuberances and pinholes. The thickness and continuity of completed epoxy coatings shall be measured using a magnetic thickness gauge.

(c) Damaged areas of epoxy coatings shall be repaired by cleaning the damaged areas to bare metal, feathering back the adjacent areas with coarse grade sand-paper and re-applying the coatings.
17.4.10 Bituminous Coatings to Steel Piles

(a) Bituminous coating material, or primer if the bituminous coating consists of a built-up system, to steel piles shall be applied within two hours of blast cleaning. The thickness of bituminous coatings shall be at least 300 \( \mu \text{m} \).

(b) Damaged areas of bituminous coatings shall be cleaned back and overcoated with the same bituminous coating material to restore the specified thickness.

(c) Steel H-piles shall be protected with a bituminous coating for eight (8) metres below cut-off level.

17.4.11 Surface Treatment of Extended Steel Piles

The splice areas of steel piles which are extended in-situ shall be prepared by blast cleaning prior to splicing. The protective coating shall be re-applied to the splice area before the piles are driven.

17.4.12 Removal of Protective Coatings to Steel Piles

Protective coatings shall be removed from the heads of steel piles which will be encased in concrete by blast cleaning or flame cleaning. The coatings shall be removed to a level of 75 mm above the underside of the concrete into which the pile will be encased.

17.4.13 Handling and Storage of Piles

(a) The identification number, grade of steel and length of pile shall be marked on steel piles.

(b) Piles shall be stored horizontally off the ground on level supports and in a manner which will not result in damage to the coatings. Bituminous coated piles shall not be stacked.

(c) Different types and sizes of piles shall be stored separately.

17.4.14 Handling and Storage of Bentonite

Bentonite shall be handled and stored in a manner which will not result in spillages on Site. It shall be stored in cool dry conditions and particular care shall be taken with bulk storage to prevent balling of the bentonite powder due to damp, or deterioration of properties due to damp and heat.

17.5 SUBMISSIONS

17.5.1 Particulars of Piling Works

(a) The following particulars of the proposed materials and methods of construction for piling works shall be submitted to the Project Manager for review:

(i) details of Contractor's Equipment;

(ii) methods and sequence of installation of piles, including methods of avoiding damage to adjacent piles, structures and utilities and measures to be taken to deal with hard material and obstructions;
(iii) details of material for steel piles, including mill certificates;

(iv) calculations of driving stresses;

(v) methods of jointing and lengthening piles;

(vi) details of reinforcement splices;

(vii) methods of controlling groundwater, or groundwater treatment;

(viii) anticipated ground vibration, ground movement and groundwater drawdown, methods of instrumentation and monitoring, and details of monitoring and measurement instrumentation;

(ix) methods and sequence of excavation, including methods of supporting excavations and of cleaning the excavation;

(x) methods of concreting or grouting;

(xi) details of protective coatings to steel piles, including manufacturers' literature;

(xii) details of preliminary piles; and

(xiii) methods of testing, including details of the specialist firm, independent from the Contractor, proposed to carry out non-destructive testing of welds and the programme for integrity testing.

17.5.2 Particulars of Construction using Bentonite Slurry

(a) The following particulars of the proposed materials and methods of construction using slurry containing bentonite or other similar agent shall be submitted to the Project Manager for review:

(i) a certificate for bentonite showing the type, the manufacturer's name, the date and place of manufacture and including details of the apparent viscosity range in Pa.s and the gel strength range in N/m² for solids in water;

(ii) characteristics of the bentonite slurry in a freshly mixed condition and in the excavation immediately before concreting;

(iii) methods of quality control, sampling, testing, mixing, storing, recirculating, removing silt and sand, preventing spillages and disposal from Site;

(iv) head of bentonite slurry, including stability calculations;

(v) details of guide walls;

(vi) methods of placing concrete by tremie; and

(vii) sequence of construction.
17.5.3 Particulars of Minipiles

(a) The following particulars of the proposed materials and methods of construction for minipiles shall be submitted to the Project Manager for review:

(i) details of pile head, reinforcement and permanent steel casing including spacers and couplings;

(ii) details of grout mix as stated in Clause 21.4.3 including fine aggregate and admixtures as appropriate;

(iii) sequence and timing of grouting, including details of secondary pressure grouting;

(iv) method of installation including equipment to be used, sequence of operations, drilling methods, casing installation and time of grouting; and

(v) minimum length of rock socket for each pile.

17.5.4 Particulars of Rock-Socketted Steel H-piles in Pre-Bored Holes

(a) The following particulars of the proposed materials and methods of construction for rock-socketted steel H-piles shall be submitted to the Project Manager for review:

(i) details of pile head, steel H-pile and the external casing, including splice joint and welding details;

(ii) details of grout mix as stated in Clause 21.4.3 including fine aggregate and admixtures as appropriate;

(iii) sequence and timing of grouting, including details of secondary pressure grouting;

(iv) method of installation including equipment to be used, sequence of operations, drilling methods, casing installation and time of grouting; and

(v) minimum length of rock socket for each pile.

17.5.5 Particulars of Continuous Flight Auger Piles

(a) The following particulars of the proposed materials and methods of construction for continuous flight auger piles shall be submitted to the Project Manager for review:

(i) details of reinforcement including spacers and couplings;

(ii) details of grout mix as stated in Clause 21.4.3 including fine aggregate and admixtures as appropriate;

(iii) sequence and timing of grouting, including details of secondary pressure grouting;

(iv) method of installation including equipment to be used, sequence of operations, drilling methods, casing installation and time of grouting; and

(v) length of piles when designed as friction piles or rock socket detail when designed as end bearing piles.
17.6 WORKMANSHIP

17.6.1 Commencement of Piling Works

Piling works, including groundwater control and ground treatment for piling works, shall not commence until:

(a) “Site Safety Supervision Plan” and “Quality Supervision Plan” as stipulated in the PNAP 242 are submitted to the satisfaction of the Buildings Department and the Project Manager;

(b) consent to the commencement of piling works has been given by the Buildings Department; and

(c) proposed materials and methods of construction, including construction and testing of preliminary piles, have been reviewed without objection by the Project Manager.

17.6.2 Prevention of Damage due to Piling Works

(a) Piling works shall not damage any structure, utility service or previously installed pile. The position of existing utilities shall be determined and underground utilities adjacent to the piles shall be exposed or otherwise accurately located before piling works start.

(b) All necessary measures shall be taken to minimise the settlement of the ground and adjacent structures and utilities and to prevent the formation of cavities in the ground resulting from piling works.

(c) The vibrations due to piling works at previously installed piles measured in terms of peak particle velocity shall not exceed 25 mm/s.

(d) The vibrations due to piling works at other structures and installations in terms of peak particle velocity shall not exceed the values stated in Table 17.1 or such limits imposed by the Project Manager or the Buildings Department.

(e) Instruments for monitoring purposes shall be installed as required by the Project Manager and the Buildings Department prior to commencement of piling works. Recording of vibrations due to piling works shall be in accordance with the requirements of Clause 7.5.18.

Table 17.1 : Restrictions on Peak Particle Velocity

<table>
<thead>
<tr>
<th>Type of structure or installation</th>
<th>Peak particle velocity (mm/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water retaining structures</td>
<td>13</td>
</tr>
<tr>
<td>Water mains</td>
<td>25</td>
</tr>
<tr>
<td>Passenger terminal complex</td>
<td>15</td>
</tr>
<tr>
<td>Sha Lo Wan directional beacon</td>
<td>1</td>
</tr>
<tr>
<td>For all other structures</td>
<td>25</td>
</tr>
</tbody>
</table>
17.6.3 Monitoring of Noise, Bibration, Ground Movement and Groundwater Level

(a) Measurements of noise level, vibration, ground movement and groundwater level shall be taken when piling works are being carried out, at locations and time intervals as stated in the Contract or as proposed by the Contractor and reviewed without objection by the Project Manager. Records of the measurements shall be kept on Site by the Contractor, and a copy of the records submitted to the Project Manager for review. The Contractor shall submit a copy of the records to the Buildings Department as necessary. Arrangements for installing instruments and taking measurements both inside and outside the Site shall be made by the Contractor.

(b) Measurements of noise level and vibration shall be made with instruments of a type reviewed without objection by the Project Manager.

(c) Sufficient numbers of piezometers and survey points shall be installed to allow the changing groundwater levels and the effects on structures, utilities and previously installed piles to be measured. Measurements shall be taken at regular intervals as specified in the Contract when groundwater control is carried out and until such time as the groundwater has resumed its natural regime.

(d) The Contractor shall inform the Project Manager immediately of any unanticipated change in measurements.

(e) If the specified limits on vibration, groundwater movement or groundwater level are exceeded, the work causing the limits to be exceeded shall be stopped immediately and particulars of proposed changes to the methods of construction shall be submitted to the Project Manager for review. Work shall not recommence until the revised methods have been reviewed without objection by the Project Manager.

17.6.4 Ground Investigation for Piling Works

(a) Prior to the commencement of piling, pre-drilling of boreholes of minimum Nx size shall be sunk by a Registered Specialist Contractor (Ground Investigation Field Work) in accordance with PNAP 66, PNAP 132, PNAP 242 and all other relevant PNAPs to determine the soil and/or rock characteristics and to determine the appropriate founding level of non-displacement cast-in-situ piles.

(b) The Contractor shall ensure that the Registered Specialist Contractor (Ground Investigation Field Work) (RSC (GIFW)) accurately logs and places cores in the correct order in specially constructed core boxes. The RSC (GIFW) shall clearly mark the corehole numbers on the cores and the boxes. Logging of cores shall be performed by a suitably qualified person in accordance with PNAP 132. The Contractor shall notify the Project Manager before the start and at the completion of core drilling.

(c) Core logs and photographic records of cores shall be submitted to the Project Manager for review within 7 days of completion of the drilling and shall be in a format suitable for submission to Buildings Department.

(d) The Contractor shall store the cores on Site during the Contract and shall relocate or dispose of the cores and boxes as directed by the Project Manager.

(e) Unless otherwise stated in this section, drilling for ground investigation for piling works shall be carried out in accordance with the requirements of Section 8 of this General Materials and Workmanship Specification.
Soil samples and rock samples shall be taken by the Contractor from pile excavations for visual inspection and testing. The method of sampling and testing shall be as stated in Section 8 of this General Materials and Workmanship Specification.

17.6.5 Founding Levels and Obstructions

(a) Prior to commencement of piling founded on rock, pre-boring should be carried out by a RSC (GIFW), such that the quality of the founding rock can be identified and the appropriate founding levels can be determined.

(b) Pre-boring

(i) The RSC (GIFW) shall pre-bore each pile location in accordance with PNAP 66 and the cores shall be minimum Nx size.

(ii) The RSC (GIFW) shall accurately log and place the cores in the correct order in properly constructed core boxes supplied by the RSC (GIFW) and clearly mark the corehole numbers on the cores and boxes. The logging of the core shall be carried out by a suitably qualified person in accordance with PNAP 132 and the Contractor shall notify the Project Manager before the start and at the completion of core drilling.

(iii) Core logs and a photographic record of all cores shall be submitted to the Project Manager for review within seven (7) days of completion of core drilling, in a format suitable for submission to Buildings Department.

(iv) The Contractor shall store the cores on Site during the Contract and shall relocate or dispose of these cores and boxes as directed by the Project Manager.

(c) Pile shafts shall be excavated to founding levels in accordance with founding criteria shown on the Employer's Drawings. This shall be established at each pile location by means of the site investigation pre-bore as specified in Clause 17.6.5(b)(i).

(d) Unless otherwise stated in the Contract, the pile base shall be levelled and shall fully penetrate the founding stratum in the case where it is on an inclined plane.

(e) The Contractor shall notify the Project Manager immediately the pile founding level is reached. The Contractor shall also submit, for the Project Manager’s review, a sample of the material taken from the arisings at the proposed pile founding level.

(f) Unless otherwise stated in the Contract, bored cast-in-situ piles shall be founded on and continue into rock in accordance with the founding criteria shown on the Employer’s Drawings, or for a minimum depth of 800 mm, whichever is the greater.

(g) Obstructions are objects encountered during installation of piles that impede or stop the pile being installed in accordance with the founding criteria shown on the Employer’s Drawings or specified strata. Obstructions shall be broken out or drilled through to enable the pile to be installed in accordance with the founding criteria shown on the Employer’s Drawings or specified strata.
17.6.6 Preliminary Piles

(a) Preliminary piles shall be constructed using the materials and methods of construction proposed for the working piles and which have been submitted to the Project Manager for review. The installation of preliminary piles shall be as follows:

(i) drill a borehole adjacent to the proposed location of each preliminary pile, before it is driven, to determine the geotechnical conditions;

(ii) install the piles at a location outside the permanent structure and to the anticipated founding depth;

(iii) test the preliminary pile by “Pile Driving Analyser” with CAPWAP analysis after installation to the founding depth reviewed without objection by the Project Manager;

(iv) carry out loading testing on the preliminary piles in accordance with PNAP 66 and PNAP 242 immediately after driving to determine the ultimate shaft friction and end bearing capacity of each of the piles; and

(v) cut off each preliminary pile two metres below the finished ground level, or as directed by the Project Manager, after completion of the loading test.

(b) The relevant piling works shall not commence until the construction, testing and records of the preliminary piles have been reviewed without objection by the Project Manager.

17.6.7 Support for Driven Piles

(a) Driven piles shall be supported and restrained by means of leaders, trestles, temporary supports or other guide arrangements in such a manner that:

(i) the piles are maintained in position and alignment;

(ii) the piles are not loosened in the ground; and

(iii) damage resulting from oscillation, vibration or movement of free-standing piles does not occur.

(b) The supports and restraints shall be maintained at all times during driving and until the piles are self supporting.

17.6.8 Followers

(a) Followers or long dollies shall not be used unless reviewed without objection by the Project Manager and permitted by the Buildings Department. If permitted, the set shall be revised by the Contractor and submitted to the Project Manager in a format suitable for submission to the Buildings Department for review, to allow for the reduction in effectiveness of the hammer blows.

(b) Whenever followers are used, the Contractor shall assess the energy reduction factor of each follower for each pile size and submit the calculations to the Project Manager, in a format suitable for submission to the Buildings Department, for review without objection.
(c) The energy reduction factor of the follower shall be taken as :

\[
\text{Energy imparted to the pile immediately after the introduction of follower} = \frac{\text{Energy imparted to the pile immediately before the introduction of follower}}{\text{Energy imparted to the pile immediately after the introduction of follower}}
\]

(d) The energy reduction factor for every combination of follower and pile size shall be determined by averaging the results of 5 sets of dynamic pile tests performed at or near to the set of 5 different piles of the same size.

17.6.9 Marking of Piles

Piles, including temporary and permanent casings, shall be marked at 1 m intervals before pitching.

17.6.10 Driving Piles

(a) Each pile, other than sheet piles, shall be driven without interruption until the required depth or set has been achieved. If a minimum depth of penetration is stated in the Contract, the Contractor shall submit to the Project Manager for review his proposals for achieving this requirement. The Contractor shall ensure that the minimum penetration and set are achieved without causing damage to the pile.

(b) The sequence and method of driving piles shall minimise the detrimental effects of heave and lateral displacement of the ground and cause the least possible displacement to previously installed piles. The Contractor shall drive piles from the centre of the pile group and work outwards. Piles, including casings, shall not be driven within a centre to centre distance of 3 m or five times the diameter of the pile or casing, whichever is less, from an unfilled excavation or from an uncased concrete pile which has been cast for less than 48 hours.

(c) The Contractor shall inform the Project Manager without delay of any sudden change in driving characteristics. The Contractor shall investigate the cause of any sudden change in driving characteristics and further driving shall not continue until these investigations have been completed and the results reviewed without objection by the Project Manager.

17.6.11 Precast Concrete Piles

The use of precast concrete piles is not permitted.

17.6.12 Displaced Piles

Piles which have been displaced as a result of driving adjacent piles shall be corrected. Particulars of the method of correction and measures to be taken to avoid displacement in subsequent driving shall be submitted to the Project Manager for review.
17.6.13 Re-drive Checks

(a) Re-drive checks shall be carried out on all preliminary piles and as directed by the Project Manager. The pile driving formula proposed by the Contractor shall be revised if the final set on re-driving is more than the final set achieved during the initial driving.

(b) Preliminary piles which fail the re-drive check shall be deemed unacceptable. Additional preliminary piles shall be proposed together with the revised pile driving formula for the review of the Project Manager.

(c) No re-drive checks shall be carried out within 24 hours of completion of first driving.

17.6.14 Lengthening Driven Piles

(a) Pile Joints

The strength of piles at joints shall not be less than the strength at any normal section of the pile. Lengthened piles shall not be driven until the joint has developed the designed strength. Pile joints shall be tested as stated in the Contract.

(b) Splicing and Welding

(i) Splicing of H-piles shall be carried out in accordance with the requirements shown on the Employer’s Drawings.

(ii) Welding for splicing of H-piles shall be carried out in accordance with Section 22 of this General Materials and Workmanship Specification.

(iii) Testing of welding for splicing of H-piles shall be carried out in accordance with Sections 17.7.8(a) and 17.7.8(b).

(iv) Piles shall be accurately located and aligned during welding. The Contractor shall ensure that the straightness of the complete pile shall not deviate by more than 3 mm along a 3 m straight edge or by 1 in 1,000 overall.

17.6.15 Measurement of Set and Working Load Capacity of Driven Piles

(a) Set shall be measured for each driven pile in the presence of the Project Manager and reviewed without objection by the Project Manager. The final set shall be measured as either:

(i) penetration per 10 blows; or

(ii) the number of blows required to produce 25 mm penetration.

(b) If driving is interrupted for more than 30 minutes, set shall not be measured after driving restarts until at least 20 blows of the same driving energy as at final set have been struck.
(c) When final set is measured:

(i) the exposed part of the pile shall be in good condition without damage or distortion;

(ii) the dolly and packing shall be in sound condition;

(iii) the final hammer blows shall be in line with the axis of the pile and the impact surfaces shall be flat and at right angles to the axes of the pile and hammer; and

(iv) the hammer shall be in good condition and operating correctly.

(d) The temporary compression of each driven pile shall be measured.

(e) The Contractor shall notify the Project Manager at least 1 hour before final set and temporary compression are to be measured.

(f) Piles shall be driven by hydraulic hammer. The Contractor shall assess the pile working load capacity according to a pile-driving formula (e.g. the modified Hiley Formula with the adoption of a single efficiency factor for hydraulic hammer, Kh, multiplied by the impact energy. The value of Kh shall be reviewed without objection by the Project Manager and the Buildings Department). The factor of safety shall not be less than two (2) for ultimate driving resistance against working load.

(g) The pile-driving formula shall be calibrated against load tests carried out on preliminary piles and checked as other piles are tested. The pile-driving formula and correlation with test loading data shall be submitted to the Project Manager for review prior to carrying out piling works other than preliminary piles.

(h) The pile shall not be considered to have attained the theoretical calculated safe loading capacity should the penetration at final set be in excess of the value reviewed without objection by the Project Manager.

(i) The temporary compression of the driving cap shall be taken as not less than 7.5 mm when hardwood packing at the pile head and in the dolly are 100 mm thick.

17.6.16 Excavation for Cast-In-Situ Piles

(a) Excavation for cast-in-situ concrete piles shall be carried out by mechanical methods; blasting and compressed air shall not be used.

(b) The stability of excavation for cast-in-situ concrete piles shall be maintained where necessary by:

(i) temporary casings;

(ii) permanent casings; or

(iii) a thixotropic slurry containing bentonite or other similar agent reviewed without objection by the Project Manager.

(c) The bottom of casings shall be kept sufficiently deep to prevent the flow of soil into the casing.
(d) Permanent casings shall not be used within temporary casings.

(e) Drilling fluids shall not be used.

(f) Where an enlarged base of a cast-in-situ concrete pile is required, this shall be formed by under-reaming with reverse circulation heads.

17.6.17 Excavation for Barrettes

(a) Excavation for barrettes shall be carried out by mechanical methods; blasting shall not be used.

(b) The stability of excavations for barrettes shall be maintained by a thixotropic slurry containing bentonite or other similar agent reviewed without objection by the Project Manager.

(c) The height of guide walls for barrettes shall be such that the head of slurry shall ensure the stability of excavations and prevent movement of the adjacent ground in excess of that specified in the Contract. The position, alignment and level of guide walls shall be checked at regular intervals and submitted for review by the Project Manager.

17.6.18 Excavation for Minipiles

The Contractor shall install minipiles without the use of bentonite slurry or other drilling muds. The stability of excavations for minipiles shall be maintained where necessary by permanent casings which shall:

(a) be manufactured from Grade 43 mild steel;

(b) have a minimum thickness of 4.5 mm;

(c) have an internal diameter of not less than the finished pile diameter shown or as scheduled on the Employer’s Drawings;

(d) be free from distortion and internal projections throughout the whole length which might prevent the proper formation of the piles; and

(e) be of uniform cross-section throughout the whole length.

17.6.19 Design and Construction of Minipiles

The design and construction of minipiles shall be in accordance with guidelines provided in PNAP 66, PNAP 242 and all other relevant PNAPs.

17.6.20 Grouting Trials for Minipiles

Grouting trials shall be carried out to demonstrate accurate control of water/cement ratio, consistency of mixing, satisfactory workability and achievement of strength requirements. The trial shall be carried out on one minipile which is considered representative of those which are to be constructed in the Permanent Works and at a location reviewed without objection by the Project Manager.
17.6.21 Inclination of Piles

The Contractor shall check the inclination of every inclined pile at each stage, during installation. The Contractor shall arrange for a number of piles, as directed by the Project Manager, to be checked by the use of an inclinometer or other method reviewed without objection by the Project Manager, before grouting. The Contractor shall record the inclination and orientations of the holes and submit the records to the Project Manager for review.

17.6.22 Excavation for Socketted Steel H-piles

(a) The prebored holes shall be large enough to allow a minimum cover of 40 mm to the steel H-piles.

(b) A temporary casing, the quality of which has been reviewed without objection, shall be provided in the pre-boring process down to at least 500 mm or such depth as required, below rockhead level, to prevent soil from falling into the pre-bored hole.

(c) Before the steel H-pile is inserted in the pre-bored hole, the hole should be cleaned with air flushing to ensure that it is free from debris and soil.

(d) Extraction of the temporary casing shall be carried out while the grout is sufficiently workable to ensure that the grout is not lifted with the casing. A vibratory extractor, which has been reviewed without objection by the Project Manager, may be used.

17.6.23 Construction using Bentonite Slurry

(a) Excavation using bentonite slurry

(i) Excavations for piles using bentonite slurry shall be filled with slurry from the time that excavation commences until concreting is complete. The slurry shall be maintained at a level of at least 1 m above the level of the external groundwater and such that the slurry pressure exceeds the pressure exerted by the soil and ground water.

(ii) If there is a loss of bentonite slurry from the excavation which is sufficient to result in a lack of stability, the excavation shall be immediately filled with material previously reviewed without objection by the Project Manager. The cause of the loss of slurry shall be investigated and excavation shall not recommence until remedial action, reviewed without objection by the Project Manager, has been taken.

(b) Mixing of bentonite slurry

(i) Bentonite shall be thoroughly mixed with water in a colloidal mixer. The water for bentonite shall be clean, uncontaminated and from a source reviewed without objection by the Project Manager. The Contractor shall test the water in accordance with the requirements of Section 20A.8.3. The water shall be at a temperature of at least 5°C. The temperature of the bentonite slurry shall be at least 5°C when supplied to the excavation.

(ii) If the groundwater is excessively saline or chemically contaminated, the bentonite shall be pre-hydrated or the bentonite slurry shall be modified such that the slurry is suitable to support the excavation.
Disposal of benetonite slurry

Any remaining bentonite slurry shall be removed from the Site and disposed in accordance with Section 7.

17.6.24 Fixing Reinforcement for Piles

(a) Fixing reinforcement for large diameter bored piles and continuous flight augur piles

Prefabricated reinforcement cages for piles shall be marked and fitted with spacers to ensure that the cage is correctly orientated and positioned within the pile.

(b) Fixing reinforcement to minipiles

Reinforcement shall be lengthened by staggering the couplers using methods reviewed without objection by the Project Manager. Each reinforcement bar shall be separated by spacers at regular intervals.

17.6.25 Cleaning and Drying Excavations for Piles

(a) The bases of excavations for piles shall be cleaned by air lifting before concrete is placed. If excavation is carried out under water, cleaning shall continue until the water is clear and free from particles of soil. Measures shall be taken to prevent the accumulation of silt and other material at the base of the excavation.

(b) If the excavation for piles is supported by bentonite slurry:

(i) the Contractor shall take measures to remove all silt or other material at the base of the boring. The Contractor shall remove heavily contaminated bentonite suspension, which could impair the free flow of concrete from the pipe of the tremie, from the bottom of the hole; and

(ii) the Contractor shall take a sample of the bentonite suspension from the base of the boring using a sampling device reviewed without objection by the Project Manager. If the specific gravity of the suspension exceeds 1.25 the placing of concrete shall not proceed, and the bentonite shall be replaced.

(c) Provided the rate of ingress of water does not exceed 0.3 l/s, the base of excavations for piles shall be dried immediately before concrete is placed.

17.6.26 Placing Concrete in Piles

(a) Each pile shall be concreted as soon as practicable. Concrete shall be placed without interruption until the complete pile is concreted.

(b) In the event that excavations for piles are supported by bentonite slurry or if the rate of ingress of water exceeds 0.3 l/s, the Contractor shall comply with the following:

(i) concrete shall be placed by tremie;

(ii) the hopper and pipe of the tremie shall be clean and watertight throughout. The pipe shall extend to the base of the boring and a sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the pipe of the tremie and the water or drilling fluid. After the first charge of concrete the pipe shall at all times penetrate the concrete which has previously been placed and shall not be withdrawn from the concrete until completion of
the concreting. Sufficient concrete shall be maintained within the pipe to ensure that the pressure from it exceeds that from the water or drilling fluid. The internal diameter of the pipe of the tremie shall be not less than 150 mm for concrete made with 20 mm aggregate. It shall be so designed that external projections are minimized, allowing the tremie to pass through reinforcing cages without causing damage. The internal face of the pipe of the tremie shall be free from projections;

(iii) the minimum cement content of the concrete shall be 375 kg/m³;

(iv) the level of the top of the concrete in piles shall be at least 1 m above the specified cut-off level; and

(v) if the top of the guide wall of barrettes is at the specified cut-off level, concrete shall continue to be placed until the top of the pile is free from contamination.

(c) Operations which in the opinion of the Project Manager are likely to disturb or affect the concrete or placing of the concrete shall not be carried out.

(d) For piles concreted in dry conditions, the concreted level shall be not less than 150 mm and not more than 500 mm above the specified cut-off level. For piles cast using tremie concrete, the concrete level shall be not less than 1 m and not more than 2 m above the specified cut-off level.

(e) The Contractor shall trim back the concrete of all piles to final cut-off level. Trimming back shall be carried out at least 7 days after placing the concrete.

17.6.27 Grouting for Piling Works

(a) Grout material shall be mixed by weight batching. The amount of water used shall be measured by a calibrated flowmeter or a measuring tank. The mixing time in high speed mixers shall be suitable for the type of mixer used. After mixing, the grout shall be continuously agitated in a holding tank and screened before injection.

(b) Before grouting, the bottom of the hole shall be flushed by high pressure air.

(c) The grout intake volume should be measured with a flowmeter accurate to ±1 litre. The Contractor shall calibrate the flowmeter and submit a calibration report to the Project Manager 7 days before trial mix of grout is made. Each pile shall be cast-in one continuous operation and under no circumstances shall a pile be left partially grouted.

17.6.28 Removal of Temporary Casings to Piles

(a) A sufficient quantity of concrete shall be maintained within temporary casings being withdrawn to ensure that the pressure from external water or soil is exceeded and that the pile is not reduced in section or contaminated.

(b) Temporary casings in contact with concrete and not withdrawn before the initial set of the concrete shall be left in place.

(c) The Contractor shall take precautions reviewed without objection by the Project Manager in all cases where excess heads of water or drilling fluid could be caused as the casing is withdrawn due to the displacement of water or fluid by the concrete as it flows into its final position against the walls of the shaft.
(d) Where two or more discontinuous lengths of casing (double casing) are used in the construction, the proposed method of working shall be reviewed without objection by the Project Manager.

17.6.29 Empty Bores above Piles

Empty bores and shafts which remain above the pile after concrete has been placed shall be temporarily protected or filled with material, of a type which has been reviewed without objection by the Project Manager as soon as practicable.

17.6.30 Tolerances: Steel Bearing Piles

Dimensional tolerances of steel bearing pile sections shall comply with the BS 4360, BS 5950 and BS 5400 as stated in Section 22.3.1. Fabrication tolerances for steel bearing piles and related steelwork shall comply with BS 5950:Part 2.

17.6.31 Tolerances: Pile Installation

(a) Piles, including mini-piles, shall be installed to within the tolerances stated in Table 17.2.

(b) Piles which do not comply with the specified tolerances shall not be forcibly corrected.

Table 17.2: Tolerances of Installed Piles

<table>
<thead>
<tr>
<th>Description</th>
<th>Tolerance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deviation from specified position in plan, measured at cut-off level</td>
<td>75 mm</td>
</tr>
<tr>
<td>Deviation from vertical</td>
<td></td>
</tr>
<tr>
<td>(a) all piles except bored piles</td>
<td>1 in 75</td>
</tr>
<tr>
<td>(b) bored piles</td>
<td>1 in 300</td>
</tr>
<tr>
<td>Deviation of raking piles from specified batter</td>
<td>1 in 25</td>
</tr>
<tr>
<td>Deviation from specified cut-off level</td>
<td>-25 mm, +0</td>
</tr>
</tbody>
</table>

The diameter of cast in-situ piles shall be at least 97% of the specified diameter at all points.

17.6.32 Remedial Works to Out of Tolerance Piles

(a) In the event that one or more piles are identified as being outside the tolerances for installed piles, the Contractor shall submit proposals for remedial works to the Project Manager for review, in a format suitable for submission to the Buildings Department, within 10 days of the completion of the piling work survey.

(b) The Contractor’s remedial works proposals shall include design calculations and Contractor’s Drawings prepared by a registered structural engineer. The proposals shall show the extent of additional reinforcement necessary such that stresses in the pile and related structure are within acceptable limits.

(c) Remedial works shall be carried out upon approval and consent by the Buildings Department and review without objection by the Project Manager, prior to commencing any works over the affected pile.
17.7 INSPECTION TESTING AND COMMISSIONING

17.7.1 Quality Supervision for Piling Works

The Contractor shall comply with the requirements for quality supervision in accordance with PNAP 242.

17.7.2 Inspection of Piling Works

(a) Before placing concrete in piles, the Contractor shall arrange Koden tests to be carried out on each pile by an independent testing body reviewed without objection by the Project Manager. The Contractor shall submit the test report to the Project Manager prior to placing concrete in piles.

(b) The Contractor shall notify the Project Manager before placing concrete in piles.

17.7.3 Inspection of Installed Piles

(a) If directed by the Project Manager, installed piles shall be exposed for inspection or testing. Excavations for exposing piles shall be of a depth reviewed without objection by the Project Manager, and the face of the excavation shall be at least 750 mm from the face of the pile. The excavation shall be maintained in a stable condition and kept free from water.

(b) The surface of the pile shall be washed clean of all silt, mud or other adhering materials to permit inspection.

(c) After inspection, excavations for exposing piles shall be filled using suitable fill material, of a type reviewed without objection by the Project Manager, which shall be compacted to obtain a relative compaction of at least 95% above the groundwater table.

17.7.4 Post Construction Proof Drilling

(a) Post construction proof drilling shall be carried out after the construction of piles in accordance with PNAP 66, PNAP 132 and PNAP 242.

(b) For large diameter bored piles and barrettes where core-drilling at the concrete/rock interface is to be carried out at each pile, the concrete shall be in contact with rock at the interface. If imperfections such as a thin layer of sediment, segregated concrete, honeycomb are found, the Contractor shall submit remedial proposals to the Project Manager, for review, in a format suitable for submission to the Buildings Department.

17.7.5 Testing: Load Tests on Piles

(a) Testing: load tests on piles

(i) The number of piles to be tested by load testing shall be as stated in the Contract or as required by the Buildings Department, whichever is the greater.

(ii) The piles shall be tested to determine the settlement of the pile under load. Testing shall be carried out in accordance with the method of testing as stated in PNAP 66 and requirements imposed by the Buildings Department.

(iii) Piles shall not be tested until the concrete or grout has attained sufficient strength to withstand the tests. The Contractor shall notify the Project Manager 7 days prior to the commencement of the test.
(iv) Records of pile load tests shall be kept by the Contractor and submitted to the Project Manager within 24 hours of each test completion. The records shall be kept on the standard forms as shown in Appendix A17.6.

(b) Compliance criteria: load tests on piles

Unless otherwise stated in the Contract, the results of load tests on piles shall comply with criteria described in PNAP 66 and requirements imposed by the Buildings Department.

(c) Non-compliance: load tests on piles

If the result of any load test on piles does not comply with the specified requirements for settlement, the Contractor shall submit remedial proposals to the Project Manager for review. In the event the remedial proposal involves any change of design, the design calculations and Contractor’s Drawings shall be prepared by a registered structural engineer and shall be submitted to the Project Manager for onward submission to Buildings Department for approval. No remedial works shall be undertaken, before review without objection by the Project Manager and approval by the Buildings Department.

17.7.6 Testing: Concrete Cores from Piles

(a) Samples: concrete cores from piles

(i) The number of concrete cores to be provided for testing from concrete piles shall be the larger of, the number required to satisfy the Buildings Department, and the number stated in the Contract. The positions from which the cores are taken shall be as directed by the Project Manager.

(ii) Concrete cores shall be 100 mm diameter.

(iii) The method of taking concrete cores shall be in accordance with CS1.

(iv) Holes formed by taking concrete cores from piles shall be reinstated using non-shrink concrete or grout, of the same characteristic compressive strength as the concrete of the pile and reviewed without objection by the Project Manager.

(b) Testing: concrete cores from piles

(i) Each concrete core from a pile shall be inspected for evidence of segregation of the constituents and for the presence of voids. Specimens selected from each core shall be tested to determine the compressive strength.

(ii) The method of preparing, inspecting and testing concrete cores shall be as stated in Section 20.8.17.

(c) Compliance criteria: concrete cores from piles

The compliance criteria for concrete cores from piles shall be as stated in PNAP 66 and Section 20.8.18.
(d) Non-compliance: concrete cores from piles

(i) If the result of any test on a concrete core from a pile does not comply with PNAP 66 and/or Clause 20.8.18, additional cores shall be taken from the same pile and additional tests shall be carried out.

(ii) Additional concrete cores shall be 100 mm diameter for concrete of 20 mm nominal maximum aggregate size and 150 mm diameter for concrete of 40 mm nominal maximum aggregate size. The number of additional cores shall be as directed by the Project Manager.

(iii) If the result of any additional test does not comply with the compliance criteria for concrete cores the Contractor shall submit remedial proposals to the Project Manager for review. The number of additional piles and additional tests shall be as directed by the Project Manager.

17.7.7 Testing: Non-destructive Tests on Welds in Piles

(a) Testing: non-destructive tests on welds in piles

(i) The number and type of non-destructive tests on welds in piles shall be as stated in the Contract or as required by the Buildings Department, whichever is the greater.

(ii) Radiographic tests shall comply with BS 2600:Part 1 and ultrasonic tests shall comply with BS 3923:Part 2.

(b) Non-compliance: non-destructive tests on welds in piles

If the result of any test on a weld in a pile does not comply with the specified requirements, the complete weld shall be cut out, the joint shall be re-welded and the weld shall be retested.

17.7.8 Testing: Integrity Tests

(a) Testing: sonic and vibration tests on piles

(i) In all bored cast-in-situ piles excavated by machine the Contractor shall install three 50 mm and one 150 mm internal diameter steel tubes securely tied to the reinforcement cage. The tubes shall be extended to the full depth of the pile and terminate above the finished concrete level. The tubes shall be watertight, corrosion free, continuous with sealed joints and with the top and bottom sealed with a 2.0 mm thick steel plate welded to the tube. The tubes shall be equally spaced around the piles. The Contractor shall submit details of the proposed method of installation of the tubes for the Project Manager's review.

(ii) The Contractor shall carry out sonic tests at cast-in-situ pile at locations reviewed without objection by the Project Manager to verify the integrity and homogeneity of the pile.

(iii) The Contractor shall carry out vibration tests at all cast-in-situ piles which have not been sonic tested to verify the integrity and homogeneity of these piles.

(iv) Sonic and vibration testing shall be carried out by an independent testing company.
(v) The Contractor shall submit the details of the proposed independent testing company and the proposed procedures for sonic and vibration testing to the Project Manager for review without objection.

(vi) All reports, in accordance with Section 17.7.5(e), and photographic traces from sonic and vibration tests shall be submitted to the Project Manager for review within 48 hours of completion the test.

(vii) All tubes shall be cut-off flush with the concrete and filled with non-shrink grout having the same characteristic compressive strength as the concrete on completion of all testing.

(b) Non-compliance : sonic and vibration testing

If the results of any sonic or vibration test indicate that the pile does not comply with the specified requirements or indicate any weakness or discontinuity in the pile, additional tests shall be carried out by the Contractor to confirm that the quality and bearing capacity of the pile satisfy the requirements of the Contract and the Buildings Department.

17.7.9 Testing: Bentonite Slurry

(a) Samples: bentonite slurry

(i) Samples of bentonite slurry shall be provided for testing at a frequency reviewed without objection by the Project Manager. Samples for testing to determine the density of the slurry shall be provided each day. A sample of bentonite slurry taken from the base of the excavation shall be tested to determine the density of the slurry before placing of concrete.

(ii) The method of sampling and the sampling apparatus shall be reviewed without objection by the Project Manager.

(b) Testing: bentonite slurry

(i) Each sample of bentonite slurry shall be tested to determine the density, viscosity, shear strength and pH value.

(ii) The method of testing shall be as stated in Table 17.3.

(iii) The measuring device for testing density shall be readable and accurate to ±0.005 g/mL.

(iv) Samples to be tested for viscosity using the Fann viscometer shall be screened before testing using a 300 μm BS test sieve.

(c) Compliance criteria : bentonite slurry

(i) The results of tests on bentonite slurry shall be as stated in Table 17.3.

(ii) Tests to determine the shear strength and pH value shall be discontinued if the results of tests indicate that a consistent working pattern has been established, taking account of the mixing process, blending of freshly mixed and previously used slurry and processes used to remove impurities from previously used slurry. If there is a subsequent change in the established working pattern, the tests to determine shear strength and pH value shall be re-introduced.
(d) Non-compliance: bentonite slurry

If the results of tests for density and viscosity do not comply with the specified requirements, or if the results of tests for shear strength or pH value do not indicate a consistent working pattern, the bentonite slurry shall be deemed unsuitable for the work and concrete shall not be placed in the slurry. The slurry shall be replaced or its composition adjusted before concrete is placed.

Table 17.3: Properties of Bentonite Slurry and Methods of Testing

<table>
<thead>
<tr>
<th>Property at 20°C</th>
<th>Test Results</th>
<th>Method of Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density as supplied to excavation</td>
<td>≤ 1.10 g/mL</td>
<td>Mud density balance</td>
</tr>
<tr>
<td>Density at base of excavation before placing concrete</td>
<td>≤ 1.25 g/mL</td>
<td>Mud density balance</td>
</tr>
<tr>
<td>Viscosity</td>
<td>30 – 50 seconds</td>
<td>Marsh cone method or Fann viscometer</td>
</tr>
<tr>
<td>Viscosity</td>
<td>≤ 0.02 Pa.s</td>
<td>Fann viscometer</td>
</tr>
<tr>
<td>Shear strength (10 minute gel strength)</td>
<td>1.4 – 10 N/m²</td>
<td>Shearometer or Fann viscometer</td>
</tr>
<tr>
<td>pH value</td>
<td>8 – 12</td>
<td>pH indicator paper strips or electrical pH meter</td>
</tr>
</tbody>
</table>

17.7.10 Testing of Grout

(a) Definition of batch

A ‘batch’ of grout is any quantity of grout used for grouting in one continuous operation in one day.

(b) Test for bleeding and free expansion

(i) One sample of grout from each batch shall be provided for testing not more than 30 minutes after mixing and protected from changes in moisture content before tests are carried out.

(ii) Each sample shall be divided into 3. Each third shall be placed in a covered cylinder with a diameter of 100 ± 10 mm to a depth of 100 ± 5 mm and the amount of bleeding and free expansion shall be measured by a scale fixed to the outside of the cylinder.

(iii) If the result of any test for the amount of bleeding or free expansion of the grout does not comply with the specified requirements, proposed changes to the materials, grout mix or method of production shall be submitted to the Project Manager for review without objection.

(c) Flow cone efflux test

(i) One sample from each batch shall be taken and tested in accordance with ASTM C939-94 to determine the “Flow Cone Efflux” time.

(ii) Grout mixes containing additives with an efflux time of less than 15 seconds shall be rejected.
17.7.11 Testing: Dynamic Pile Test

(a) Testing: dynamic pile test

(i) In addition to load tests on piles, dynamic testing on driven piles shall be carried out by the Contractor. The dynamic pile test is a test applied to the pile by means of a falling weight, hammer or other percussive device. The response of the pile to the impact force is measured in terms of pile strain, acceleration and displacement. The results of the dynamic pile test shall allow a determination to be made by the Contractor on the load capacity of the pile. The Contractor shall take measurements at one level on the pile surface near the pile cap.

(ii) The dynamic pile testing method shall be reviewed without objection by the Project Manager prior to carrying out testing.

(iii) The number of dynamic pile tests shall be as stated in the Contract and the tests shall be carried out on piles selected by the Project Manager.

17.7.12 Records of Piling Works

(a) Records of piles delivered

Records of prefabricated piles shall be kept by the Contractor on Site and submitted to the Project Manager for review at the time the piles are delivered to Site. The records shall include test certificates, analyses and mill sheets for steel piles and proprietary piles.

(b) Records of pile installation

Records of pile installation shall be kept by the Contractor on Site and submitted to the Project Manager for review within 24 hours after the driving or installation of each pile has been completed. The records shall be kept on standard forms as shown in Appendices A17.2 to A17.4. The records and Form BA 14 shall be submitted to the Project Manager for onward submission to the Buildings Department upon completion of piling works.

(c) Records of bentonite slurry

Records of tests of bentonite slurry shall be kept by the Contractor on Site and a report shall be submitted to the Project Manager at frequencies reviewed without objection by the Project Manager. The records shall be kept on standard forms as shown in Appendix A17.5.
(d) Records of load tests on piles

Records of load tests on piles shall be kept by the Contractor on Site and a report shall be submitted to the Project Manager for review within 48 hours after the test has been completed. The records shall be kept on standard forms as shown in Appendix A17.6. The records shall include graphs showing load and settlement versus time, plotted in the format shown in BS 8004, Figure 15(a).

(e) Records of integrity tests on piles

Records of integrity tests on piles shall be prepared by an experienced engineer reviewed without objection by the Project Manager and shall be kept by the Contractor on Site and a report shall be submitted to the Project Manager for review within 48 hours after the test has been completed. The records shall be available to the Project Manager for inspection at all times. The report shall contain the following details:

(i) pile reference numbers;
(ii) measured pile length;
(iii) defects such as cracks, fractures or discontinuities; and
(iv) pile stiffness.

The Contractor shall submit the records and Form BA 14 to the Project Manager for onward submission to the Buildings Department upon completion of piling works.

17.8 OPERATION AND MAINTENANCE

17.8.1 Record Drawings

(a) Record drawings of installed piles shall be prepared by the Contractor and two copies shall be submitted to the Project Manager for review within 14 days of completing each group of the piles.

(b) The drawings shall include a plan showing characteristic features of the Site, the as-constructed co-ordinates of the centre of each pile at cut-off level, the final depth and cut-off level and size of each pile as constructed and other information to the satisfaction of the Buildings Department and the Project Manager.

(c) The Contractor shall submit record drawings and Form BA 14 to certify completion of piling works, to the Project Manager for onward submission to the Buildings Department. For the avoidance of doubt, these record drawings are in addition to the as-constructed drawings required under the Contract.
APPENDIX A17.1

DETERMINATION OF THE LOAD DEFLECTION CHARACTERISTICS OF PILES BY LOAD TEST

A17.1.1 Scope

This method determines the load deflection characteristics of piles.

A17.1.2 Equipment

The following equipment is required:

(a) Kentledge, anchor piles or other anchorages supported or installed at suitable locations to provide adequate reactions against jacking.

(b) A load measuring device which shall consist of a load column, pressure cell, or other appropriate system, calibrated before and after each series of tests, or whenever adjustments are made to the device, or at time intervals recommended by the manufacturer of the equipment.

(c) Four deflectometers accurate to 0.025 mm.

(d) Precision levelling equipment accurate to 0.25 mm.

(e) A reference frame for supporting deflectometers and providing a datum for deflectometer measurements.

(f) Working platforms.

(g) Screens and protection from exposure to conditions which may affect the test.

(h) Hydraulic loading equipment.

A17.1.3 Procedure: Before Testing

The procedure before testing shall be as follows:

(a) The kentledge, anchor piles or other anchorages shall be installed. The centre of each anchor pile shall be at least 2 m or three times the pile diameter, whichever is greater, from the centre of the pile to be tested and from the centre of any adjacent pile.

(b) If required, the pile to be tested shall be extended from cut-off level to ground level. The strength of piles at joints shall not be less than any normal section of the pile.

(c) A temporary square pile cap designed by the Contractor shall be constructed.

(d) Working platforms, screens and protection shall be installed.

(e) The reference frame shall be set up on supports which are at least 2 m or three times the pile diameter, whichever is greater, from the test pile and anchor pile. The four deflectometers shall be mounted on the reference frame to measure the deflection of the four corners of the temporary pile cap.
A17.1.4 Procedure: Load Test

The procedure for the load test shall be as follows:

(a) Preliminary piles shall be tested to not less than twice the working load of the pile. Working piles shall be tested to not less than 1.8 times working load. Reductions for group or boundary effects shall not be made in determining the test loads.

(b) Test loads shall be applied and removed in three stages as stated in Table A17.1.1.

(c) The test loads shall be applied in increments, and removed in decrements, of 25% of the working load. Increments of load shall not be applied until the rate of settlement of the pile is less than 0.1 mm in 20 minutes.

(d) The full test loads for Stage I, defined in Table A17.1.1, shall be applied in increments and shall then be maintained for at least 24 hours after the rate of settlement has reduced to less than 0.1 mm per hour. The test loads shall be removed in decrements and the recovery of the pile determined before loading is resumed.

(e) The procedure stated in Clause A17.1.4 (d) shall be repeated for Stage II, defined in Table A17.1.1, loading.

(f) The procedure stated in Clause A17.1.4 (d) shall be repeated for Stage III, defined in Table A17.1.1, loading unless the Project Manager directs the loading to be maintained for a longer period.

(g) The settlement of the pile shall be measured at hourly intervals. The settlement of the pile under each increment and decrement of loading shall be measured. The exact times at which increments are applied and decrements are removed shall be recorded. Settlements shall be measured and times shall be recorded in the presence of the Project Manager.

(h) The level of the reference beam shall be checked at regular intervals, as reviewed without objection by the Project Manager during the test.

Table A17.1.1: Test Loading Stages

<table>
<thead>
<tr>
<th>Stages</th>
<th>Test load</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>25% of max. test load</td>
</tr>
<tr>
<td>II</td>
<td>50% of max. test load</td>
</tr>
<tr>
<td>III</td>
<td>100% of max. test load</td>
</tr>
</tbody>
</table>

A17.1.5 Procedure: After Testing

After testing, equipment shall be removed, temporary pile caps shall be demolished and pile extensions shall be removed to cut-off level. Anchor piles shall be withdrawn.

A17.1.6 Reporting of Results

The following shall be reported:

(a) The loads applied to the nearest 0.05 t.

(b) The settlement of the pile to the nearest 0.05 mm at hourly intervals and under each increment and decrement of loading.

(c) The exact times at which increments were applied and decrements removed.

(d) The levels of the reference beam, to the nearest 0.05 mm.
APPENDIX A17.2

PILE DRIVING RECORD
(Prefabricated steel and driven cast-in-place piles)

Contract No. __________________________ Title __________________________

Contractor  ____________________________________________________________

Pile data

Reference No. ______________ Location ________________________________

Type __________________________ Size ________ Rake __________________

For steel piles; Length __________________________

Drive system data

Hammer: type _______ mass _______ kg drop (at set) _______ mm rated energy _______ kJ

Helmet, dolly & anvil : type __________________________ mass __________________ kg

Packing : type ________ condition ___________ thickness ___________ mm

Levels

Commencing ground/sea bed* level (PD/CD)* ________________________________

Depth of overburden/height of working platform above ground/sea bed level __________

Reference working level/platform level* ________________________________

<table>
<thead>
<tr>
<th>Date &amp; Time</th>
<th>Drop (m)</th>
<th>Depth penetrated (m)</th>
<th>No. of blows+</th>
<th>Cumulative No. of blows</th>
<th>Length of individual segments, location of splices and tests carried out</th>
<th>Remarks (State details of obstruction, delays, interruptions and location of concrete samples++)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

+       per 0.25 m for top 3.0 m of pile
++      for cast in place piles

(*delete as appropriate)
### PILE DRIVING RECORD

**(Prefabricated steel and driven cast-in-place piles)**

Temporary compression record (on graph paper graduated in millimetres to be pasted in space below)

<table>
<thead>
<tr>
<th>Final penetration depth</th>
<th>Top of pile level</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Temporary compression</th>
<th>Cut off level</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Final set</th>
<th>Pile head level</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm/last 10 blows</td>
<td></td>
</tr>
<tr>
<td>or</td>
<td></td>
</tr>
<tr>
<td>mm</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Deviation from plumb or rake 1 in</th>
<th>Deviation at cut-off level x-x</th>
<th>mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>y-y</td>
<td></td>
<td>mm</td>
</tr>
</tbody>
</table>

**For driven cast-in place piles:**

<table>
<thead>
<tr>
<th>Length of temporary casing</th>
<th>Length of permanent casing</th>
<th>Length of cage reinf.</th>
</tr>
</thead>
<tbody>
<tr>
<td>mm</td>
<td>mm</td>
<td>m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Concrete grade</th>
<th>Date of concreting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Theoretical volume of concrete required \( m^3 \)

<table>
<thead>
<tr>
<th>Actual volume of concrete placed</th>
<th>( m^3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( m^3 )</td>
</tr>
</tbody>
</table>

Reported by _________________________  Verified by _________________________

Contractor's Representative  Project Manager's Representative

Date _________________________  Date _________________________

(* delete as appropriate)
APPENDIX A17.3

PILE RECORDS

(Bored cast-in-place piles)

Contract No. ____________________ Title ________________________________

Contractor ________________________________

Pile data

Reference No. ________________ Location ________________________________

Type _______ Diameter _____ mm  Design Length _____ mm  Rake 1 in _____

Bore hole record

Commencing ground/sea bed* level (P.D./C.D.)* ____________________________

Depth of overburden/height of working platform above ground/sea bed level _________ m

Casing/drilling fluid* type ________________

Reference working level/platform level* ________________________________

<table>
<thead>
<tr>
<th>Date &amp; Time</th>
<th>Depth penetrated</th>
<th>Details of strata penetrated/ground water level</th>
<th>Details of soil testing, proving of bedrock and under-ream</th>
<th>Remarks (State details of obstruction, delays interruptions, and location of concrete samples)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Deviation from plumb or rake 1 in ______  Deviation at cut-off level x-x ______ mm  y-y ______ mm  

Length of temporary casing _________ m  Length of permanent casing _____________ m

(*delete as appropriate)
# PILE RECORDS

(Bored cast-in-place piles)

## Bore hole condition prior to concreting

Bottom visible/invisible* | Measured depth of bore | m
---|---|---
Depth of water/drilling fluid* | | m

Damage and debris observations

## Concrete record

Concreting in dry/by tremie* | Water inflow rate | litres/second
---|---|---
Concrete grade | | 
Slump

Actual concreted level | Cut off level |
---|---|
Lt %

Overall __ = _____________ %
La

Length of cage reinforcement | m
---|---

<table>
<thead>
<tr>
<th>Date &amp; Time</th>
<th>Delivery note No./ Truck load No.</th>
<th>Quantity (m³)</th>
<th>Theoretical length filled Lt(m)</th>
<th>Actual Length Placed La (m)</th>
<th>Lt % La</th>
<th>Cumulative length placed (m)</th>
<th>Remarks (Interruptions in placing, cause of excessive Lt ± __%, Location of La concrete samples, Ref. No. of cubes taken, etc.)</th>
</tr>
</thead>
</table>

Reported by Contractor's Representative | Verified by Project Manager's Representative

Date ______________________ Date ______________________

Note: The Project Manager shall be informed of any deviation greater than ±10% from the expected (theoretical) level of concrete placed.

(* delete as appropriate)
APPENDIX A17.4

PILE RECORDS

(Barrettes)

Contractor No. ___________________________  Title ____________________________

Contractor ________________________________________________________________

Pile data

Reference No. ___________________________  Location __________________________

Size of barrette __________________________  Shape ____________________________

Design Length __________________________ m

Excavation data

Commencing ground level (PD) __________ Depth of overburden __________________ m

Guide wall levels: top ____________________  bottom ____________________________

<table>
<thead>
<tr>
<th>Date</th>
<th>Depth reached (m)</th>
<th>Details of Strata penetrated/surrounding ground water level</th>
<th>Details of soil testing, proving of bedrock, and under-ream</th>
<th>Remarks (State details of obstructions, interruptions and delays)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Deviation from plumb 1 in ____________ Deviation at cut-off level x-x, mm

y-y __________ mm

Base level of excavation ____________ m

Depth of base from top of guide wall ____________ m
### PILE RECORDS

**(Barrettes)**

**Concrete record**

Concrete grade __________________________  Slump __________________________

Actual concreted level _________________  Cut off level __________________________

Lt
Overall __________ = __________________________ %
La

Length of cage reinforcement _____________ m

<table>
<thead>
<tr>
<th>Date &amp; Time</th>
<th>Delivery note No./ Truck load No.</th>
<th>Quantity (m³)</th>
<th>Theoretical length filled Lt (m)</th>
<th>Actual Length Placed La (m)</th>
<th>Lt % La</th>
<th>Cumulative length placed (m)</th>
<th>Remarks (Interruptions in placing, cause of excessive Lt ± ___ %, Location of La concrete samples, Ref. No. of cubes taken, etc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Report by ____________________________  Verified by ____________________________

Contractor's Representative  Project Manager's Representative

Date ____________________  Date ____________________

Note  The Project Manager shall be informed of any deviation greater than ± 10% from the expected (theoretical) level of concrete placed.

(*delete as appropriate)
APPENDIX A17.5

BENTONITE SLURRY RECORDS

Contract No. ________________  Title _______________________

Contractor _____________________________________________

Sample data

Ref. No. of pile ________________  Location ___________________

Sources of test sample:
(a) freshly mixed slurry*
(b) as supplied to excavation*
(c) from bottom of excavation prior to placing concrete*

Date & time of sampling __________________________________

<table>
<thead>
<tr>
<th></th>
<th>Test Method and Apparatus Used</th>
<th>Test Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density (g/mL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Viscosity (seconds)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sand Content (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluid Loss (mL)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature (°C)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Remarks : -
________________________________________________________________________
________________________________________________________________________
________________________________________________________________________

Reported by __________________________  Verified by __________________________
Contractor's Representative  Project Manager's Representative

Date __________________________  Date __________________________

(* delete as appropriate)
APPENDIX A17.6

PILE LOAD TEST RECORD

(Test result)

Contract No. ___________________  Title ____________________

Contractor ______________________________________________________________________________________

Pile data

Reference No. ___________________  Location ____________________

Type ___________________  Size ____________________

Pile dia/diagonal width (D) ____________  Gross pile length (Lp) ______________

Sectional area (A) _________________  Young's modulus (E) ______________

Testing data

Design working load (P) _______________________________________________________________________

Test load (Q) = 2 (P) ____________________

Pressure gauge No. ____________  Calibration Certificate ref. ____________  Date ____________

<table>
<thead>
<tr>
<th>Dial gauge number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Serial number</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calibration certificate ref.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Date of calibration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Level of fixed point on load reaction system: before testing ___________________________
  after testing _______________________
  ground settlement = _______________________

<table>
<thead>
<tr>
<th>Date &amp; Time</th>
<th>Load (kN)</th>
<th>Pressure Gauge Reading</th>
<th>Dial Gauge Readings</th>
<th>Cumulative Settlement (mm)</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Dial 1  Dial 2  Dial 3  Dial 4  Average</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# PILE LOAD TEST RECORDS

**Test result**

<table>
<thead>
<tr>
<th>Load in kN</th>
<th>1000</th>
<th>2000</th>
<th>3000</th>
<th>4000</th>
<th>5000</th>
<th>6000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Settlement in mm</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Maximum settlement at working load: (Allowable = 20 mm for buildings and 10 mm for all other structures)
Actual = ____________________________

Settlement at maximum test load (S₁): (Allowable = S₁ less than twice settlement at 90% of maximum test load (2S₂).)
Actual S₁ = ________________________  2S₁ = ____________________________

Reported by ________________________  Verified by ________________________
Contractor's Representative  Project Manager's Representative

Date ____________________________  Date ____________________________

(delete as appropriate)
[this page not used]
SECTION 18 FORMWORK AND FINISHES TO CONCRETE

18.1 GENERAL

18.1.1 General requirements

The works and materials specified herein shall comply with the Sections stated, unless otherwise stated in this Section:

(a) surface finish to concrete carriageways shall comply with Section 10;
(b) cover spacers for steel reinforcement shall comply with Section 19; and
(c) materials for cement mortar shall comply with Section 20.

18.2 DEFINITIONS AND ABBREVIATIONS

18.2.1 Class

“Class” is a term used to identify the different types and standards of formed, unformed and treated finishes.

18.2.2 Falsework

Falsework is a temporary structure used to support formwork and the permanent structure until the permanent structure is self-supporting.

18.2.3 Formed finish

Formed finish is the finish of the concrete surface produced by the use of formwork.

18.2.4 Formwork

Formwork is the mould against which concrete is cast and which gives the shape and finish to the concrete surface.

18.2.5 Permanent formwork

Permanent formwork is formwork designed to remain in position as part of the Permanent Works.

18.2.6 Profiled formwork, trough moulds and waffle moulds

(a) Profiled formwork is formwork designed to produce a ribbed or patterned finish on the concrete surface.
(b) Trough mould is the mould used with complementary moulds to create an elongated recess in the underside of a slab.
(c) Waffle mould is the mould used with complementary moulds to create square recesses in a concrete slab.
18.2.7 Sealed plywood

Sealed plywood is plywood which has been sealed with a factory-applied film of phenolic resin or plastic material.

18.2.8 Spatterdash

Spatterdash is a mixture of cement, coarse sand, granite fines and water, used as a rendering on concrete surfaces.

18.2.9 Treated finish

Treated finish is the finish of the concrete surface produced by a treatment applied to a formed or unformed finish.

18.2.10 Unformed finish

Unformed finish is the finish of the concrete surface produced without formwork and by working the concrete surface before the concrete has hardened.

18.3 DESIGN AND PERFORMANCE CRITERIA

18.3.1 Design of falsework and formwork

(a) Falsework and formwork shall be designed, in accordance with the Specification, to maintain the position and shape of the formwork such that the hardened concrete surface complies with the characteristics of finish stated in Table 18.1.

(b) Falsework and formwork shall be capable of being dismantled and removed without shock, disturbance, damage or loading to the concrete and in such a manner that the specified requirements for removing or leaving in position side formwork, soffit formwork and falsework will be achieved without disturbing other formwork or falsework.

(c) Formwork shall be used to form the top surface of concrete inclined at a slope exceeding 15° to the horizontal unless it can be demonstrated that the specified finish will be produced without the use of formwork. Formwork to top surfaces shall be anchored to prevent floatation.

18.4 MATERIALS

18.4.1 Formwork

(a) Formwork shall be timber, metal, plastic, fibreglass or other material which will produce the specified finish. Materials used as formers for profiled formwork, chamfers, splays, rebates and other features shall be such that they produce the same finish as the main formwork.

(b) Plywood for formwork shall have a close, uniform grain and the edges shall be sealed with barrier paint, polyurethane varnish or other impermeable material.

(c) The faces of formwork for Class F3, F4, F5 and F6 finishes shall have a uniform texture and a matt, not a shiny or polished, surface. The edges of the formwork shall be straight and square.
18.4.2 Formwork class of finish

(a) The characteristics of each class of finish shall be as stated in Tables 18.1, 18.2 and 18.3.

(b) Formwork of the type stated in Table 18.1 shall produce a concrete surface which complies with the characteristics of finish stated in Table 18.1.

(c) Unless otherwise shown on the Employer's Drawings, the class of formed and unformed finish required for different concrete surfaces shall be as stated in Table 18.4. The higher class of finish shall start at least 150 mm below the finished ground level for concrete surfaces which are partly buried.

18.4.3 Release agents

(a) Release agents shall be a proprietary type reviewed without objection by the Project Manager. Release agents containing mineral oils shall not be used. Barrier paint, polyurethane varnish, wax or other materials shall not be used instead of a release agent.

(b) Release agents shall not:

(i) stain or colour the concrete;

(ii) affect the bond between the concrete and subsequent coverings; or

(iii) have an adverse effect on any finishes to be applied to the concrete.

(c) Release agents other than those which incorporate a surface retarder to produce a Class T1 finish shall not affect the hardening of the concrete.

(d) Release agents used on formwork for water retaining structures for potable and fresh water shall be non-toxic and shall not impart a taste to the water.

(e) Release agents used on steel formwork shall contain a rust-inhibiting agent.

(f) Release agents used on formwork for Class F4, F5 and F6 finishes shall be a chemical release agent.

(g) On areas of formwork which are likely to be affected by pedestrian traffic, rain or dust, release agents for Class F4, F5 and F6 finishes shall be a type which evaporates to leave a dry film on the formwork, unless protection from such effects is provided.
<table>
<thead>
<tr>
<th>Class of finish</th>
<th>Type of formwork normally used</th>
<th>Characteristics of finish</th>
<th>Formwork pattern</th>
<th>Abrupt irregularities permitted</th>
<th>Gradual irregularities permitted</th>
<th>Specific requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>F1</td>
<td>Sawn timber</td>
<td></td>
<td>Not required</td>
<td>&lt; 10 mm</td>
<td>&lt; 15 mm in 2 m</td>
<td>No specific requirements</td>
</tr>
<tr>
<td>F2</td>
<td>Plywood</td>
<td></td>
<td>Pattern of formwork joints and tie holes as stated in Clause 18.6.4 (a) and (b)</td>
<td>&lt; 5 mm</td>
<td>&lt; 10 mm in 2 m</td>
<td>Even surface No grout runs</td>
</tr>
<tr>
<td>F3</td>
<td>Sealed plywood or fibreglass or steel</td>
<td></td>
<td></td>
<td>&lt; 3 mm</td>
<td>&lt; 5 mm in 2 m</td>
<td>Even surface No grout runs No grain pattern</td>
</tr>
<tr>
<td>F4</td>
<td>Sealed plywood or fibreglass or steel</td>
<td></td>
<td></td>
<td>&lt; 2 mm</td>
<td>&lt; 5 mm in 2 m</td>
<td>Uniform, dense and smooth surface No grout runs No grain pattern No crazing No major blemishes No staining or discolouration Blowholes up to 5 mm dia.</td>
</tr>
<tr>
<td>F5</td>
<td>Sealed fibreglass or Steel</td>
<td></td>
<td></td>
<td>&lt; 1 mm</td>
<td>&lt; 5 mm in 2 m</td>
<td>Uniform, dense and smooth surface No grout runs No grain pattern No crazing No major blemishes No staining or discolouration Blowholes up to 3 mm dia. No holes or embedded metal parts</td>
</tr>
<tr>
<td>F6</td>
<td>Sealed plywood</td>
<td></td>
<td>Pattern of formwork stated in Clause 18.6.4.(a)</td>
<td>&lt; 3 mm</td>
<td>&lt; 5 mm in 2 m</td>
<td>As F4 but no internal ties and/or embedded metal parts allowed</td>
</tr>
</tbody>
</table>
Table 18.2 : Unformed Finishes

<table>
<thead>
<tr>
<th>Class of finish</th>
<th>Method of producing finish</th>
<th>Characteristics of finish</th>
<th>Abrupt irregularities permitted</th>
<th>Gradual irregularities permitted</th>
<th>Specific requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>U1</td>
<td>Levelling the surface of the compacted concrete with a screed board</td>
<td>Screed marks &lt; 5 mm</td>
<td>&lt; 10 mm in 2 m</td>
<td>No specific requirements</td>
<td></td>
</tr>
<tr>
<td>U2</td>
<td>Forming a Class U1 finish and tamping the surface</td>
<td>Tamp marks &lt; 10 mm</td>
<td>Not applicable</td>
<td>Ridged surface</td>
<td></td>
</tr>
<tr>
<td>U3</td>
<td>Forming a Class U1 finish and wood floating, steel trawelling or power floating the surface</td>
<td>Float marks &lt; 3 mm</td>
<td>&lt; 10 mm in 2 m</td>
<td>Uniform, dense and smooth surface</td>
<td></td>
</tr>
<tr>
<td>U4</td>
<td>Forming a Class U3 finish and brushing the surface with a stiff brush</td>
<td>Brush marks &lt; 3 mm</td>
<td>&lt; 10 mm in 2 m</td>
<td>Rough texture</td>
<td></td>
</tr>
<tr>
<td>U5</td>
<td>Forming a Class U3 finish and steel trawelling the surface under firm pressure or power floating the surface</td>
<td>Nil</td>
<td>&lt; 5 mm in 2 m</td>
<td>Uniform, dense and smooth surface, free from trowel marks No staining or discolouration</td>
<td></td>
</tr>
</tbody>
</table>

Table 18.3 : Treated Finishes

<table>
<thead>
<tr>
<th>Class of finish</th>
<th>Type of finish</th>
<th>Method of producing finish</th>
<th>Characteristics of finish</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Exposed aggregate</td>
<td>Washing and brushing the concrete surface</td>
<td>Cement matrix removed and coarse aggregate exposed to a depth not exceeding one-third of the nominal maximum coarse aggregate size</td>
</tr>
<tr>
<td>T2</td>
<td>Point tooled</td>
<td>Point tooling the concrete surface</td>
<td>Cement matrix and aggregate surface removed sufficiently to expose the aggregate with a minimum penetration into the matrix between aggregates</td>
</tr>
<tr>
<td>T3</td>
<td>Bush hammered</td>
<td>Bush hammering the concrete surface</td>
<td>Cement matrix and aggregate surface removed</td>
</tr>
<tr>
<td>T4</td>
<td>Broken rib</td>
<td>Hammering or chiselling the edges and faces of the concrete surface</td>
<td>Fragments of concrete ribs removed</td>
</tr>
<tr>
<td>T5</td>
<td>Light blasting</td>
<td>Blasting the concrete surface by abrasives</td>
<td>Cement matrix removed and coarse aggregate exposed to a depth not exceeding one-third of the nominal maximum coarse aggregate size</td>
</tr>
<tr>
<td>T6</td>
<td>Heavy blasting</td>
<td>and compressed air or by water jetting</td>
<td>Cement matrix removed and coarse aggregate exposed to a depth not exceeding one-third of the nominal maximum coarse aggregate size</td>
</tr>
</tbody>
</table>
### Table 18.4: Class of Finish

<table>
<thead>
<tr>
<th>Description of surface</th>
<th>Formed</th>
<th>Unformed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surfaces to be covered</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- screeded</td>
<td>F2</td>
<td>U2</td>
</tr>
<tr>
<td>- rendered, plastered</td>
<td>F2</td>
<td>U3</td>
</tr>
<tr>
<td>- tiled</td>
<td>F4</td>
<td>U5</td>
</tr>
<tr>
<td>- painted</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Surfaces for treated finishes</td>
<td>F3</td>
<td>U3</td>
</tr>
<tr>
<td>Surfaces for pedestrian traffic</td>
<td>-</td>
<td>U4</td>
</tr>
<tr>
<td>Construction joints (for Class T1 finish)</td>
<td>F2</td>
<td>U3</td>
</tr>
<tr>
<td>Movement joints</td>
<td>F3</td>
<td>U3</td>
</tr>
<tr>
<td>Benching, screeds</td>
<td>F3</td>
<td>U5</td>
</tr>
<tr>
<td>Blinding, foundations, pile caps</td>
<td>F1</td>
<td>U1</td>
</tr>
<tr>
<td>Piers, blocks, pipe surrounds</td>
<td>F1</td>
<td>U1</td>
</tr>
<tr>
<td>- below FGL</td>
<td>F2</td>
<td>U3</td>
</tr>
<tr>
<td>- above FGL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Manholes, chambers</td>
<td>F1</td>
<td>U1</td>
</tr>
<tr>
<td>- external below FGL</td>
<td>F2</td>
<td>U3</td>
</tr>
<tr>
<td>- external above FGL</td>
<td>F2</td>
<td>U3</td>
</tr>
<tr>
<td>- internal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Culverts, channels</td>
<td>F1</td>
<td>U1</td>
</tr>
<tr>
<td>- external below FGL</td>
<td>F2</td>
<td>U3</td>
</tr>
<tr>
<td>- external above FGL</td>
<td>F4</td>
<td>U5</td>
</tr>
<tr>
<td>- internal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Water retaining structures</td>
<td>F2</td>
<td>U3</td>
</tr>
<tr>
<td>- external below FGL</td>
<td>F4</td>
<td>U5</td>
</tr>
<tr>
<td>- external above FGL</td>
<td>F4</td>
<td>U5</td>
</tr>
<tr>
<td>- internal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Buildings</td>
<td>F1</td>
<td>U1</td>
</tr>
<tr>
<td>- external below FGL</td>
<td>F2</td>
<td>U3</td>
</tr>
<tr>
<td>- external above FGL</td>
<td>F4</td>
<td>U5</td>
</tr>
<tr>
<td>- internal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bridges, retaining walls, walls</td>
<td>F1</td>
<td>U1</td>
</tr>
<tr>
<td>- below FGL</td>
<td>F4</td>
<td>U5</td>
</tr>
<tr>
<td>- above FGL, not exposed to direct public view</td>
<td>F5</td>
<td>U5</td>
</tr>
<tr>
<td>- above FGL, exposed to direct public view</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- internal, not exposed to direct public view</td>
<td>F2</td>
<td>U1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Class of finish</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Formed</td>
<td>F1</td>
<td>U1</td>
</tr>
<tr>
<td>Unformed</td>
<td>F2</td>
<td>U2</td>
</tr>
<tr>
<td></td>
<td>F4</td>
<td>U4</td>
</tr>
<tr>
<td></td>
<td>F5</td>
<td>U5</td>
</tr>
</tbody>
</table>
18.4.4 Formwork ties

(a) Formwork ties shall not be used in any structure which bears against the ground or retains water.

(b) Formwork ties and components shall be a type such that any removable part can be removed without damaging the concrete; any part left in the concrete shall be at least 40 mm or the specified nominal cover to the reinforcement, whichever is greater, from the concrete surface.

(c) Formwork ties and components used with profiled formwork shall be a type such that holes left by the ties and components are small enough to be located completely within the recesses in the concrete surface.

18.4.5 Cement mortar for concrete surfaces

(a) All formwork ties and component holes including blowholes shall be filled.

(b) Cement mortar for filling blowholes shall consist of cement and fine aggregate together with the minimum amount of water necessary to achieve a consistency suitable for completely filling the blowholes.

(c) Cement mortar for filling holes left by formwork ties and components shall consist of 1 part of cement to 3 parts of fine aggregate together with the minimum amount of water necessary to achieve a consistency suitable for compacting the mortar into the holes. The mix shall contain a non-shrink admixture.

(d) Cement mortar for filling blowholes and holes left by formwork ties and components in concrete surfaces with Class F4, F5 and F6 finishes shall be the same colour as the hardened concrete; light-coloured sand or white cement may be used for this purpose.

18.4.6 Surface retarder

Surface retarders shall be a proprietary type reviewed without objection by the Project Manager and shall not stain or colour the concrete.

18.4.7 Abrasives

Abrasives for blasting shall be grit and shall not contain any silica, iron, clay or other materials which will stain or colour the concrete.

18.5 SUBMISSIONS

18.5.1 Particulars of formwork and finishes to concrete and samples of materials

(a) Particulars and samples of the proposed materials and methods of construction for Class F3, F4, F5, F6, U5 and T finishes shall be submitted to the Project Manager for review as marked ‘x’ in Table 18.5. The same particulars shall be submitted for other classes of finish if required by the Project Manager. For formwork Class F5 and F6, the extent of each pour shall be proposed by the Contractor and reviewed without objection by the Project Manager so that no visible difference occurs in concrete surfaces in the same general plan.
(b) The particulars and samples submitted for formed, unformed and treated finishes shall include details for trial panels.

(c) Design calculations for formwork and falsework, in accordance with the requirements of Section 2 of this General Materials and Workmanship Specification, shall be submitted to the Project Manager for review.

Table : 18.5 : Particulars to be Submitted

<table>
<thead>
<tr>
<th>Particulars to be submitted</th>
<th>Formed finishes</th>
<th>Unformed finishes</th>
<th>Treated finishes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formwork drawings : Panel/trough/waffle construction</td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>- Layout and pattern of panels/troughs/waffles, joints, rebates and formwork ties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>: Column construction</td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>- Layout and pattern of column moulds, joints rebates and formwork ties</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Design calculations : Check on formwork, falsework, Permanent Works</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method statement : Method statement of formwork and falsework erection, including sequence for floor slab and columns</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Samples : Formwork, F3, F4 and F5</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Formwork ties</td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Cover spaces</td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Brand name and manufacturer's literature : Release agent</td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Curing compound</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Surface retarder</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Programme : Removing formwork</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Applying treated finishes</td>
<td>-</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Details : Sources of formwork, formwork ties and cover spacers</td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Curing method</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Filling blowholes</td>
<td>X</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Filling formwork tie holes</td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
<tr>
<td>Protecting finishes</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

18.6 WORKMANSHIP

18.6.1 Trial panels

(a) A trial panel shall be constructed for each Class F4, F5, F6, U5 and T finish to demonstrate that the proposed materials, mix design, methods of production and methods of construction, including curing and removal of formwork, shall produce the specified finish.
(b) Trial panels for Class F4, F5 and F6 finishes shall be constructed before the relevant formwork for the Permanent Works is erected, and trial panels for Class U5 and T finishes shall be constructed before the relevant Permanent Works is concreted. The trial panels shall be completed at least 4 weeks before the relevant Permanent Works are programmed to commence.

(c) The Contractor shall notify the Project Manager before constructing trial panels.

(d) Trial panels shall be constructed using the materials, mix design, methods of production and methods of construction, including curing and removal of formwork, submitted to and reviewed without objection by the Project Manager.

(e) Trial panels shall be horizontal, vertical or inclined as appropriate and shall be constructed at locations reviewed without objection by the Project Manager. Unless otherwise stated in the Contract each trial panel shall be not less than 2 m by 2 m by 300 mm thick, and shall contain reinforcement representative of the most congested reinforcement which will be used in the Permanent Works. Trial panels shall incorporate formwork ties and components, horizontal joints, vertical joints, chamfers, splays, rebates and other features representative of those which will be used in the Permanent Works, including the filling of formwork ties, components and blowholes.

(f) The Contractor shall submit the trial panels to the Project Manager for review without objection. When the Project Manager has issued a notice of no objection for the trial panels, they shall become a benchmark against which all subsequent finishes of concrete surfaces shall comply. Benchmarks shall be protected from damage and shall be left in position until the Project Manager directs their removal.

18.6.2 Non-compliance: trial panels

If the Project Manager determines that the specified finish has not been produced in the trial panel, particulars of proposed changes to the materials, mix design, methods of production or methods of construction shall be submitted to the Project Manager for review and further trial panels shall be constructed until the specified finish is produced in the trial panel. Further trial mixes shall be made unless the Project Manager directs otherwise.

18.6.3 Commencement of formwork and concreting

Formwork for Class F4, F5 and F6 finishes shall not be erected and elements with Class U5 and T finishes shall not be concreted until the Project Manager has determined that the specified finish has been produced in the trial panel.

18.6.4 Changes in materials and methods of construction

The materials, mix design, methods of production or methods of construction, including curing and removal of formwork, used to produce the specified finish in the benchmarks shall not be changed unless reviewed without objection by the Project Manager.

18.6.5 Storage of formwork

(a) Formwork shall be stored off the ground on level supports and in a manner which will not result in damage, deformation or contamination of the formwork.

(b) Formwork for Class F3, F4, F5 and F6 finishes shall be covered and protected from exposure to conditions which may affect the formwork.
18.6.6 Storage of release agents and surface retarders

Release agents and surface retarders shall be stored in sealed containers marked to identify the contents and protected from exposure to conditions which may affect the material. The materials shall be stored in accordance with the manufacturers' recommendations and shall not be used after the recommended shelf life has been exceeded.

18.6.7 Construction of formwork

(a) Formwork shall not have any splits, cracks or other defects. The faces and edges of formwork shall be clean and formwork faces shall be free of projections.

(b) Formwork which has been previously used shall be repaired and the edges resealed before it is erected.

(c) Formwork shall be firmly supported and individual panels shall be rigid. Joints between formwork panels, stop ends and adjoining concrete shall be tight and shall not permit grout loss.

(d) Formwork shall be cut in such a manner that reinforcement and built-in components passing through the formwork are maintained in position; the joints shall be tight and shall not permit grout loss.

(e) Formers for profiled formwork, chamfers, splays, rebates and other features shall be rigidly and evenly fixed to the formwork along the complete length and shall not permit grout loss.

(f) Formwork ties and components shall be fixed in such a manner that they do not touch reinforcement or built-in components. Formwork ties and components shall fit tightly against formwork faces and shall not permit grout loss.

(g) If required for compaction, cleaning or inspection, temporary openings shall be provided in the formwork.

18.6.8 Construction of formwork for Class F2, F3, F4, F5 and F6 finishes

(a) Formwork panels for Class F2, F3, F4, F5 and F6 finishes shall be the same size and shall form a regular pattern as shown on the Employer's Drawings and/or reviewed without objection by the Project Manager. The lines of joints between panels shall be straight and continuous, horizontal and vertical, or inclined to suit the pattern of profiled formwork, and shall be coincident with construction joints and other joints and with recesses in the concrete surface. The number of make-up pieces shall be kept to a minimum and shall be the same material as the formwork system.

(b) Holes left by formwork ties and components in concrete surfaces with Class F2, F3 and F4 finishes shall be in line horizontally and vertically and shall form a regular pattern reviewed without objection by the Project Manager. Holes in profiled formwork shall be located in such a manner that the holes are completely within recesses in the concrete surface.

(c) Chamfers shall be provided for all external angles of 90° or less in concrete surfaces with Class F2, F3, F4, F5 and F6 finishes.

(d) Formwork for curved concrete surfaces with Class F2, F3, F4, F5 and F6 finishes shall not be made up of a series of flats or straights.
18.6.9 Construction of formwork for Class F3, F4, F5 and F6 finishes

(a) Each type of formwork for either Class F3, F4, F5 and F6 finishes shall be obtained from one source and different types of formwork shall not be mixed. Damaged formwork shall not be used. Parts of steel formwork which will be in contact with concrete shall be free from rust.

(b) For concrete surfaces with Class F3, F4, F5 and F6 finishes, joints between formwork panels shall be sealed with foamed rubber strips. The foamed rubber strips shall be sufficiently compressible to form a grout-tight joint. The width of the resulting gap between the panels shall not be greater than 1 mm and the sealing strips shall not protrude proud of the surface of the formwork panels. Joints between formwork panels shall not be sealed by tape fixed to the formwork faces.

(c) For concrete surfaces with Class F3, F4, F5 and F6 finishes, joints between the formwork and its ends, adjoining concrete and built-in components shall be sealed with gaskets of rubber or flexible foamed polyurethane; the gaskets shall be fixed firmly and evenly to the formwork. The joints shall not be sealed by tape fixed to the formwork faces, putty or other sealants.

(d) Formwork for Class F3, F4, F5 and F6 finishes shall be protected from spillages, rust marks and stains.

18.6.10 Built-in components

(a) Built-in components, void formers and box-outs shall be fixed in position before concreting. Void formers and box-outs shall not be used instead of built-in components. Polystyrene shall not be used for void formers and box-outs.

(b) Hardened concrete shall not be cut or broken to provide holes or chases without being reviewed without objection by the Project Manager.

(c) Pipe sleeves, inserts and ducts shall be securely and correctly located within the specified tolerances.

(d) Formwork for openings, chases and holes shall not interfere with the reinforcement.

18.6.11 Application of release agents

(a) A release agent shall be used on all formwork other than permanent formwork and formwork on which a surface retarder is used to produce a Class T1 finish. The release agent shall be applied by the method and at the rate of application recommended by the manufacturer or as demonstrated to be satisfactory by use in the trial panel.

(b) Formwork faces shall be cleaned before release agents are applied. Concrete, reinforcement and built-in components shall not be contaminated by release agents.

(c) Each type of release agent used on formwork for Class F3, F4, F5 and F6 finishes shall be obtained from one manufacturer and different types of release agent shall not be used on formwork for the same element.

(d) Release agents shall be applied to formwork for Class F3, F4, F5 and F6 finishes after the formwork has been erected and before the reinforcement is fixed or, if this is not practicable, immediately before the formwork is erected. The release agent covering shall be complete and uniform.
18.6.12 Times for removal of falsework and formwork

(a) Falsework and formwork shall not be loosened or removed before the minimum times stated in Table 18.6 have elapsed. The times stated are for a minimum ambient temperature of 15°C, for elements without superimposed loads and for concrete containing OPC, PPFAC or both OPC and PFA.

(b) For the purpose of determining the minimum times for loosening or removing falsework and formwork, copings at the top of columns in water retaining structures shall be classified as slabs and roof slabs in water retaining structures shall be classified as beams.

Table 18.6 : Minimum Times for Loosening or Removing Falsework

<table>
<thead>
<tr>
<th>Type of falsework or formwork</th>
<th>Class F1, F2, F3, F4 and F6 finishes</th>
<th>Class F5 finish</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Concrete without PFA</td>
<td>Concrete with PFA</td>
</tr>
<tr>
<td>Vertical (non-profiled)</td>
<td>12 hours</td>
<td>15 hours</td>
</tr>
<tr>
<td>(profiled)</td>
<td>7 days</td>
<td>7 days</td>
</tr>
<tr>
<td>Inclined to top surfaces</td>
<td>12 hours</td>
<td>15 hours</td>
</tr>
<tr>
<td>Soffits of slabs and ribs</td>
<td>4 days</td>
<td>4 days</td>
</tr>
<tr>
<td>(props left in)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soffits of beams</td>
<td>7 days</td>
<td>7 days</td>
</tr>
<tr>
<td>(props left in)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Props to slabs and ribs</td>
<td>10 days</td>
<td>10 days</td>
</tr>
<tr>
<td>(unloaded)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Props to beams</td>
<td>14 days</td>
<td>14 days</td>
</tr>
<tr>
<td>(unloaded)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Props to cantilevers</td>
<td>28 days</td>
<td>28 days</td>
</tr>
</tbody>
</table>

18.6.13 Removal of falsework and formwork

(a) Formwork shall be removed without hammering or levering to the concrete and in such a manner that there is no shock, disturbance, damage or loading to the concrete or damage to the specified finish. Side formwork shall be removed without disturbing soffit formwork and soffit formwork shall be removed without disturbing props except as provided for in Clause 18.6.13(b).

(b) Individual props may be removed in accordance with a programme reviewed without objection by the Project Manager to allow the removal of soffit formwork provided that the formwork has been designed accordingly and that each prop is replaced as soon as the formwork has been removed.

(c) Falsework and formwork for Class F3, F4 and F5 finishes shall be loosened and removed in a continuous operation and in accordance with a programme reviewed without objection by the Project Manager. All formwork shall be loosened before individual panels are removed and all formwork shall be removed within the programmed period. Individual panels or make-up pieces shall not be left in position.
(d) Unless formwork has been left in place for curing requirements it must be fully removed immediately after initial loosening so that curing may be carried out.

18.6.14 Unformed finishes

(a) Unformed finishes shall be produced by the methods stated in Table 18.2.

(b) Brushing to produce a Class U4 finish shall be carried out in straight lines in a direction reviewed without objection by the Project Manager. Brushing shall be carried out when the concrete has hardened sufficiently for the float marks to be removed and for the ridges to be formed without displacing the aggregate.

(c) Floating and trowelling shall not be carried out until the concrete has hardened sufficiently to allow the specified finish to be produced with the minimum amount of floating and trowelling. Excess laitance shall not be produced.

18.6.15 Treated finishes

(a) Treated finishes shall be produced by constructing a concrete surface with a Class F3 or U3 finish as appropriate and applying the treatment to the surface by the methods stated in Table 18.3. Abrupt irregularities in the concrete surface shall be removed before the treatment is applied.

(b) The treatment shall be applied in a continuous operation in accordance with a programme reviewed without objection by the Project Manager.

18.6.16 Class T1 finish

(a) Washing and brushing to produce a Class T1 finish shall not be carried out until the concrete has hardened sufficiently for the cement matrix to be removed without disturbing the coarse aggregate. After washing and brushing have been completed and the concrete surface has hardened, the surface shall be cleaned.

(b) The cement matrix shall not be removed or the aggregate exposed by mechanical methods.

(c) Class T1 finishes may be produced by using a surface retarder applied to the formwork or to the concrete surface. The surface retarder shall be applied by the method and at the rate of application recommended by the manufacturer, or as demonstrated to be satisfactory by use on the trial panel.

(d) Plywood to which a surface retarder is to be applied shall be sealed with barrier paint or polyurethane varnish. The formwork shall be removed in small sections and the coarse aggregate exposed by washing and brushing the concrete surface.

(e) Formwork to which a surface retarder has been applied shall not be re-used unless a surface retarder is to be used again on the formwork. Formwork to which a surface retarder has been applied and which is to be re-used shall be cleaned before the retarder is reapplied.
18.6.17 Class T2 and T3 finishes

Point tooling to produce Class T2 finishes and bush hammering to produce Class T3 finishes shall be carried out evenly in small areas and not in distinct lines. Tooling and hammering shall not start until at least 7 days after concreting.

18.6.18 Class T4 finish

Hammering or chiseling to produce a Class T4 finish shall be applied from only one direction and only either hammering or chiseling shall be applied, on any one face. Hammering and chiseling shall not start until at least 14 days after concreting.

18.6.19 Class T5 and T6 finishes

(a) Blasting to produce Class T5 and T6 finishes shall not be carried out until the concrete has hardened sufficiently for the cement matrix to be removed without disturbing the coarse aggregate. Adjacent surfaces shall be protected from blasting and dust shall be controlled by screens and by water-spraying.

18.6.20 Remedial and repair work on concrete surfaces

(a) Remedial or repair work shall not be carried out on concrete surfaces unless reviewed without objection by the Project Manager.

(b) Abrupt irregularities shall be removed from concrete surfaces which will be painted or to which tiles will be fixed with adhesives.

(c) For slipformed surfaces, as the concrete emerges from the shutter, any drag cracks shall immediately be closed by means of a wooden float. The surface of the concrete shall then be gently brushed horizontally to produce a light uniform texture. Any necessary cutting out of concrete shall be carried out immediately and made good as soon as possible thereafter using concrete taken from the slipforming mix with the coarse aggregate sieved out as necessary.

18.6.21 Filling blowholes and formwork tie holes

(a) Blowholes exceeding 3 mm in size in water retaining structures and watertight structures, and blowholes exceeding 10 mm in size in other structures shall be filled with cement mortar. The size of blowholes shall be the maximum dimension measured across the hole on the concrete surface. If the number and size of blowholes in concrete surfaces with Class F3 and F4 finishes is greater than in the trial panel the blowholes shall be filled.

(b) Holes left by formwork ties and components shall be cleaned and filled by ramming cement mortar into the holes in layers. Holes in concrete surfaces with a Class F4 finish shall be filled to a level slightly below the concrete surface; the holes shall not be overfilled and rubbed down.

(c) Filling of blowholes and holes left by formwork ties and components shall be carried out as soon as practicable after the Project Manager has inspected the finish and with the minimum interruption to curing. Filling of blow holes in Class F5 finish shall not be permitted.
18.6.22 Spatterdash and bonding agents

(a) Spatterdash shall consist of cement and coarse sand or granite fines in the proportions 1:2 by volume mixed with the minimum amount of water necessary to achieve the consistency of a thick slurry. Spatterdash shall be thrown with a hand trowel onto the surface to a thickness not exceeding 6 mm and shall cover at least 60% of the area which is to be plastered or rendered. Spatterdash shall be wetted one hour after application and shall be allowed to cure and harden before under coats are applied.

(b) Spatterdash shall be applied as soon as practicable after the Project Manager has inspected the finish and after the concrete surface has been cleaned and wetted.

(c) Bonding agents for attaching finishes to concrete surfaces shall be a proprietary type reviewed without objection by the Project Manager and shall be applied by the method and at the rate recommended by the manufacturer.

18.6.23 Construction Tolerances

(a) Except where otherwise specified in the Contract, deviation of concrete surfaces from the specified lines, grades and dimensions shown on the Employer's Drawings shall comply with the tolerances set-out in this sub-section.

(b) Final measurements to confirm that the Works are within the specified tolerances shall be made at 28 days after casting for in-situ construction.

(c) The specified tolerances shall not be cumulative.

(d) The permitted deviations for in-situ concrete construction shall be as follows:

(i) Variation in equivalent positions, in plan, of a concrete surface of a column or wall, between two successive pours at floor level

(ii) Variation from the vertical:
- In the lines and surfaces of concrete columns and walls
  No more than 1:300, up to 15 mm maximum measured horizontally from true vertical
- In the lines and surfaces of conspicuous items such as corners of columns, architectural rebates, etc.
  No more than 1:500, up to 10 mm maximum, measured horizontally from true vertical

(iii) Variation in normal level of floor slab, as shown on the drawings
  ± 5 mm
(iv) Variation from the horizontal (Refer Table 18.2 for unformed surfaces other than slab surfaces)
No more than 1:500, up to +10 mm, -5 mm maximum for upper slab surfaces
No more than shown in Table 18.1, up to -10 mm, +0 mm maximum for slab and rib soffits, measured vertically from true level

(v) Variation from true plan position and from correct lines
No more than 1:300, up to 15 mm maximum measured horizontally from true plan position

(vi) Variation in cross section and linear dimensions
Members up to 1500 mm dimension; +5 mm, -0 mm
Members over 1500 mm; +10 mm, -0 mm

(vii) Openings, sleeves and embedded fixtures:
- Variation of location 6 mm
- Variation of size ± 3 mm

(viii) Variation in steps:
- In a flight, maximum accumulative tolerance, rise ± 3 mm
tread ± 6 mm
- In consecutive steps, rise ± 2 mm
tread ± 3 mm

(e) The permitted deviation for in-situ concrete items associated with mechanical and electrical plant shall be as follows:

(i) Variation from verticality:
- Plinths and machine bases ± 3 mm in 8 m
  (± 3 mm max)
- Cable and pipe trenches ± 6 mm per 8 m
  (± 6 mm max)
(ii) Variation from level or specific gradient or batter:
- Plinths and machine bases \( \pm 3 \text{ mm in 8 m} \) 
  \( (\pm 3 \text{ mm max}) \)
- Cable and pipe trenches \( \pm 6 \text{ mm per 8 m} \) 
  \( (\pm 6 \text{ mm max}) \)

(iii) Variation from specified centre lines or setting out lines:
- Plinths and machine bases \( \pm 3 \text{ mm} \)
- Cable and pipe trenches \( \pm 6 \text{ mm} \)

(iv) Variation from specified cross-sectional dimensions:
- Plinths and machine bases \( \pm 3 \text{ mm} \)
- Cable and pipe trenches \( \pm 6 \text{ mm} \)
- Variation from specified position for bolt boxes \( 6 \text{ mm} \)
- Variation from specified position for 6 mm foundation bolts

(f) Notwithstanding the maximum tolerances specified in the preceding sub-sections, there shall be no misalignment at vertical or horizontal joints on exposed faces. Also, any exposed concrete face which shows an undulating or irregular surface, even though it may be within the stated tolerances, will not be accepted.

(g) Note that where a tolerance is related to a given length, the tolerance for any lesser length shall be in linear proportion thereto, subject to review by the Project Manager. For verticality, the tolerance for each lift of concrete shall be calculated on the same basis with a normal maximum of 3 mm deviation from true vertical.

18.7 INSPECTION, TESTING & COMMISSIONING

18.7.1 Inspection of formwork and reinforcement

(a) The Contractor shall allow sufficient time for the Project Manager to inspect the completed formwork and reinforcement, including trial panels, before carrying out any work, including fixing reinforcement adjacent to formwork and erecting formwork adjacent to reinforcement, which will make access to the formwork faces or reinforcement difficult.

(b) The Contractor shall allow sufficient time for the Project Manager to inspect formwork for Class F3, F4, F5 and F6 finishes before it is erected and shall notify the Project Manager before erecting the formwork.
18.7.2 Inspection of finishes

(a) Before any subsequent work is carried out on a concrete surface, the surface will be inspected by the Project Manager to determine if the specified finish has been produced. Formed finishes shall be inspected as soon as the formwork has been removed.

(b) Blowholes or holes left by formwork ties and components shall not be filled and spatterdash or other coverings shall not be applied before the inspection.

18.7.3 Compliance of finishes

(a) Concrete surfaces shall have the characteristics stated in Tables 18.1 and 18.2 for the different classes of formed and unformed finish before any subsequent work is carried out on the concrete surface and shall have the characteristics stated in Table 18.3 for the different classes of treated finish.

(b) The Project Manager will determine if the specified finish has been produced and will use the trial panels as a benchmark.

(c) Abrupt irregularities shall be measured by direct measurement. Gradual irregularities shall be measured using a 2 m long straight edge on surfaces intended to be flat and by a method reviewed without objection by the Project Manager on other surfaces.
SECTION 19 STEEL REINFORCEMENT

19.1 DEFINITIONS AND ABBREVIATIONS

19.1.1 Reinforcement Connector

“Reinforcement connector” is a coupler or sleeve designed to transmit the force between two bars in tension or compression.

19.1.2 Bar Reinforcement

“Bar reinforcement” is hot rolled steel bar or cold worked steel bar or cold reduced wire reinforcement.

19.1.3 Fabric Reinforcement

Fabric reinforcement is a mesh or grid of bar reinforcement welded in the factory in accordance with BS 4483.

19.1.4 Batch: Reinforcement

A batch of bar reinforcement, fabric reinforcement or reinforcement connectors for tension joints is any quantity of bar reinforcement, fabric reinforcement or reinforcement connectors for tension joints of the same type, size and grade, manufactured by the same mill, covered by the same mill and testing certificates and delivered to Site at any one time. In addition, for epoxy coated reinforcement and galvanized reinforcement, the coatings shall have been applied at the same coating factory and shall be covered by the same testing certificates.

19.2 MATERIALS

19.2.1 Bar Reinforcement and Fabric Reinforcement

Except where noted on the Employer's Drawings, bar reinforcement and fabric reinforcement shall comply with the following:

- Hot rolled steel bars: Construction Standard CS2
- Cold worked steel bars: BS 4461
- Steel fabric: BS 4483
- Cold reduced steel wire: BS 4482
- Deformed high yield steel bars: BS 4449, Type 2 bond classification

19.2.2 Epoxy Coatings to Reinforcement

(a) Epoxy coatings to reinforcement and patching material for epoxy coatings shall comply with ASTM A775M except as stated in Sections 19.2.2 (b), 19.4.5, 19.5.3, 19.5.4 and 19.5.8. The coatings shall be applied by the electrostatic spray method in accordance with ASTM A775M at a factory reviewed without objection by the Project Manager.
The film thickness of the coating after curing shall be at least 0.15 mm and shall not exceed 0.25 mm over the complete periphery including deformations and ribs. The bond classification of coated bars determined in bond performance tests shall not be less than that of uncoated bars.

### 19.2.3 Galvanizing to Reinforcement

(a) Galvanizing to reinforcement shall comply with BS 729. Galvanized reinforcement shall be chromate passivated as part of the galvanizing process by quenching the bars immediately after galvanizing in a solution containing at least 0.2% sodium dichromate in water. The galvanizing shall be applied after cutting and bending of the reinforcement.

(b) Metallic zinc-rich priming paint for repairs to galvanized reinforcement shall comply with BS 4652.

### 19.2.4 Reinforcement Connectors

(a) Reinforcement connectors shall be a proprietary type reviewed without objection by the Project Manager.

(b) Reinforcement connectors for tension joints shall be a cold swaged or threaded type. The connectors shall develop the full tensile strength of the parent bar and shall comprise high tensile steel studs and seamless steel tubes fitted with protective plastic caps.

(c) Reinforcement connectors for compression joints shall be wedge locking or bolted sleeve type.

(d) The concrete cover to reinforcement connectors shall not be less than the specified minimum.

(e) Reinforcement connectors shall not be used with galvanized or epoxy coated reinforcement.

### 19.2.5 Cover Spacers

(a) Cover spacers for reinforcement shall be concrete blocks or a proprietary plastic or concrete type. Proprietary cover spacers shall be reviewed without objection by the Project Manager.

(b) Cover spacers for Class F3, F4, F5 and F6 finishes shall be a proprietary plastic or concrete type. Cover spacers for epoxy coated reinforcement and galvanized reinforcement shall be a proprietary plastic type.

(c) Cover spacers shall be as small as practicable consistent with their purpose and shall be designed to maintain the specified cover to reinforcement. Cover spacers shall be capable of supporting the weight of reinforcement and construction loads without breaking, deforming or overturning.

(d) The strength and durability of concrete blocks and proprietary concrete cover spacers shall not be less than that of the surrounding concrete.

(e) Cover spacers for Class F3, F4, F5 and F6 finishes shall be of a colour similar to that of the surrounding concrete and shall not cause indentations in the formwork.
(f) The use of Site manufactured concrete spacer blocks will only be permitted if the Project Manager has reviewed without objection the method of manufacture and quality of the block.

19.2.6 Chairs, Supports and Spacers

Chairs, supports and spacers other than cover spacers for reinforcement shall be steel. The steel shall be coated with nylon, epoxy, plastic or other dielectric material for epoxy coated reinforcement and shall be galvanized for galvanized reinforcement.

19.2.7 Tying Wire

Tying wire for reinforcement adjacent to and above Class F4, F5 and F6 finishes shall be 1.2 mm diameter stainless steel wire. Tying wire for epoxy coated reinforcement shall be 1.6 mm diameter soft annealed steel wire coated with nylon, epoxy, plastic or other dielectric material. Tying wire for galvanized reinforcement shall be 1.6 mm diameter galvanized soft annealed steel wire. Tying wire for other reinforcement shall be 1.6 mm diameter soft annealed steel wire.

19.2.8 Tying Devices and Clips

Tying devices and clips for reinforcement shall be a proprietary steel type reviewed without objection by the Project Manager. Tying devices and clips for reinforcement adjacent to and above Class F4, F5 and F6 finishes shall be stainless steel. Tying devices and clips for epoxy coated reinforcement shall be coated with nylon, epoxy, plastic or other dielectric material. Tying devices and clips for galvanized reinforcement shall be galvanized.

19.3 SUBMISSIONS

19.3.1 Particulars of Bar Reinforcement and Fabric Reinforcement

The following particulars of the proposed bar reinforcement and fabric reinforcement shall be submitted to the Project Manager for review:

(a) for Class 1 bar reinforcement, a mill certificate from the quality assured stocklist in accordance with CS2 Cl.4.1.3 and a copy of the manufacturer's third party certificate;

(b) for Class 2 bar reinforcement, a mill certificate from the quality assured stocklist in accordance with CS2 Cl.4.1.4 and a copy of the manufacturer’s third party certificate;

(c) for Class 3 bar reinforcement, a mill certificate from the supplier in accordance with CS2 Cl.4.2;

(d) Upon delivery of bar reinforcement the Contractor shall submit a test report containing the details specified in CS2, Cl.3.3.3 and Cl.3.3.5; and

(e) for fabric reinforcement, a certificate form the manufacturer showing the manufacturer's name, the date and place of manufacture and showing that the reinforcement complies with the requirements stated in the Contract including details of:

(i) bond classification of deformed bar reinforcement and of fabric reinforcement;

(ii) cast analysis;
carbon equivalent value;

results of tensile, bend and rebend tests, including the effective cross-sectional area for tensile tests;

results of bond performance tests for deformed bar reinforcement and for fabric reinforcement; and

results of weld tests for fabric reinforcement.

19.3.2 Particulars of Epoxy Coatings to Reinforcement

The following particulars of the proposed epoxy coatings to reinforcement shall be submitted to the Project Manager for review:

(a) name and location of the coating factory;

(b) coating material and method of application; and

(c) a certificate from the manufacturer showing the date and place of application of the coating and showing that the epoxy coatings comply with the requirements stated in the Contract and including results of tests for:

(i) thickness of coating;

(ii) chemical resistance;

(iii) resistance to applied voltage;

(iv) chloride permeability;

(v) adhesion of coating;

(vi) bond strength to concrete;

(vii) abrasion resistance;

(viii) impact strength; and

(ix) hardness.

19.3.3 Particulars of Galvanized Coatings to Reinforcement

The following particulars of the proposed galvanized coatings to reinforcement shall be submitted to the Project Manager for review:

(a) name and location of the coating factory; and

(b) a certificate from the manufacturer showing the date and place of application of the coating and showing that the galvanized coatings comply with the requirements stated in the Contract and including results of tests for:

(i) weight of coating; and

(ii) uniformity of coating.
19.3.4 Particulars of Reinforcement Connectors

Particulars of the proposed materials and methods of installation for reinforcement connectors, including the manufacturer's literature, and tensile test results, shall be submitted to the Project Manager for review.

19.3.5 Particulars Suitable for Submission to Buildings Department

All submissions under Clauses 19.3.1 – 19.3.4 shall be in a form suitable for submission to the Buildings Department.

19.3.6 Bending Schedules

(a) Unless otherwise stated in the Contract, for works designed in detail by the Employer, any bending schedules by the Employer are provided for the information of the Contractor but are not guaranteed correct. The Contractor shall check the schedules and submit to the Project Manager for review, any amendments, additions or deductions as may be necessary to conform to the Employer's Drawings and the Specification at least 28 days before bending of the reinforcement commences.

(b) Should any alterations to the bending schedules be required by the Contractor to facilitate his sequence of construction, location of construction joints, box-outs, openings and the like, then the revised bending schedules together with explanatory notes and diagrams shall be submitted to the Project Manager for review at least 28 days before bending of the reinforcement commences.

19.3.7 Representative Samples of Materials

Representative samples of the following proposed materials shall be submitted to the Project Manager at the same time as particulars of the material are submitted:

(a) bar and fabric reinforcement;
(b) epoxy coated bar and fabric reinforcement;
(c) galvanized bar and fabric reinforcement;
(d) reinforcement connectors for tension joints and compression joints;
(e) cover spacers; and
(f) tying wire, tying devices and clips.

19.4 WORKMANSHIP

19.4.1 Handling of Reinforcement

(a) Reinforcement shall not be subjected to rough handling, shock loading or dropping from a height.

(b) Nylon, rope or padded slings shall be used for lifting epoxy coated reinforcement and galvanized reinforcement; bundles shall be lifted with a strongback or with multiple supports to prevent abrasion.
19.4.2 Storage of Reinforcement

(a) Reinforcement shall be stored off the ground on level supports and in a manner which will not result in damage or deformation to, or in contamination of, the reinforcement. Fabric reinforcement shall be stored horizontally. Where conditions of saline water exist the Contractor shall provide hard standing reviewed without objection by the Project Manager for steel storage and bending and shall prevent contact between steel and saline water.

(b) Different types and sizes of reinforcement shall be stored separately.

(c) Reinforcement shall not be stored on or adjacent to concrete surfaces which form part of the Permanent Works or existing structures.

(d) Epoxy coated reinforcement and galvanized reinforcement shall be stored on wooden or padded cribbing.

19.4.3 Cutting and Bending Reinforcement

(a) Reinforcement shall be cut and bent in accordance with BS 4466 to the specified shapes and dimensions and shall be bent at temperatures of at least 5°C and not exceeding 100°C.

(b) Epoxy coated reinforcement shall be bent cold. Bar cutting and bar bending equipment for epoxy coated reinforcement shall have padded supports and contact areas shall be fitted with nylon or plastic mandrels.

(c) Grade 460 reinforcement shall not be rebent or straightened after bending. Grade 250 reinforcement which projects from the hardened concrete may be bent aside and rebent provided that the internal radius of the bend is at least twice the diameter of the bar and that bending is not carried out by levering against the concrete or by other methods which are likely to damage the concrete.

(d) The ends of bars to be used with reinforcement connectors for compression joints shall be sawn square with all burrs removed.

19.4.4 Surface Condition of Reinforcement

(a) Reinforcement shall be clean at the time of fixing and shall be free from loose mill scale, loose rust or any substance which is likely to reduce the bond or affect the reinforcement or concrete chemically. Reinforcement shall be maintained in this condition until concrete is placed around it.

(b) If the surface condition of the reinforcement deteriorates such that it does not comply with the requirements stated in Section 19.4.4(a), the reinforcement shall be cleaned or dealt with by other methods reviewed without objection by the Project Manager, prior to being used.

19.4.5 Repairs to Epoxy Coatings and Galvanized Coatings

(a) If the coating to epoxy coated reinforcement is delaminated or split at any point or if the coating to epoxy coated reinforcement or galvanized reinforcement is damaged:

(i) at any point by an amount exceeding 25 mm² in area or 50 mm in length;
(ii) at more than three points in a 1 m length by amounts each not exceeding 25 mm² in area or 50 mm in length; or

(iii) at more than six points in the cut and bent length of a bar by amounts each not exceeding 25 mm² in area or 50 mm in length,

then that part of the reinforcement shall not be used in the Permanent Works.

(b) Damaged areas not exceeding 25 mm² in area or 50 mm in length and cut ends of epoxy coated reinforcement, other than that rejected under Section 19.4.5(a) shall be repaired using patching material applied in accordance with the manufacturer's recommendations.

(c) Damaged areas not exceeding 25 mm² in area or 50 mm in length and cut ends of galvanized reinforcement shall be repaired by applying two coats of metallic zinc-rich priming paint. Sufficient paint shall be applied to provide a zinc coating of at least the same thickness as the galvanized coating.

(d) Repairs to epoxy coatings and galvanized coatings shall be carried out within 8 hours of cutting or damage. Traces of rust shall be removed from the surface of the reinforcement before the repair is carried out.

19.4.6 Fixing Reinforcement

(a) Bar reinforcement, fabric reinforcement and reinforcement connectors for tension joints from each batch shall not be fixed until testing of the batch has been completed.

(b) Reinforcement shall be fixed rigidly in position and secured against displacement.

(c) A sufficient number of intersecting and lapping bars shall be tied using tying wire, tying devices or clips to prevent movement of the reinforcement. The ends of tying wire, tying devices and clips shall not encroach into the cover to reinforcement.

(d) Laps and joints in reinforcement shall be made only at the positions specified on the Employer's Drawings and by the specified methods except where otherwise reviewed without objection by the Project Manager in accordance with Section 19.3.5(b).

(e) Sufficient numbers of cover spacers, chairs, supports and spacers other than cover spacers shall be provided to maintain the reinforcement in the correct location and to maintain the specified cover at all positions. Cover spacers, chairs, supports and spacers other than cover spacers shall be placed at a maximum spacing of 1.5 m. Chairs, supports and spacers other than cover spacers shall be positioned adjacent to or above cover spacers and shall have at least the same cover as that specified for the reinforcement.

(f) Prefabricated reinforcement cages shall be rigidly supported and braced before moving.

(g) Reinforcement which is free-standing shall be secured in position and braced to prevent movement due to wind and other loads.

19.4.7 Fixing Reinforcement Connectors

Reinforcement connectors shall be fixed in accordance with the manufacturer's recommendations and using equipment recommended by the manufacturer.
19.4.8 Welding of Reinforcement

Reinforcement shall not be welded.

19.4.9 Exposed Reinforcement

Reinforcement which is to be left exposed shall be protected by coating with cement slurry. The bars shall be cleaned and recoated by the same method if the original coating has begun to deteriorate.

19.4.10 Access Over Reinforcement

Reinforcement shall not be contaminated or displaced as a result of access over the reinforcement; access shall be obtained by using planks and ladders.

19.4.11 Tolerances: Reinforcement

(a) Tolerances on cutting and bending reinforcement shall comply with BS 4466, Table 1, 2 and 4.

(b) Unless otherwise stated on the Employer's Drawings, reinforcement shall not be out of the designed position by more than 5 mm and shall not encroach into the minimum specified cover.

(c) Reinforcement bars may be moved as necessary to avoid interference with other reinforcing steel or embedded items. If bars are moved more than one bar diameter or enough to exceed the above tolerance, the resulting arrangement of bars shall be subject to review without objection by the Project Manager.

19.5 INSPECTION TESTING AND COMMISSIONING

19.5.1 Inspection of Reinforcement

The Contractor shall allow sufficient time for the Project Manager to inspect the completed reinforcement before carrying out any work, including erecting formwork adjacent to reinforcement, which will make access to the reinforcement difficult. The Contractor shall notify the Project Manager before carrying out such work.

19.5.2 Samples: Reinforcement

(a) Samples of bar reinforcement, fabric reinforcement and reinforcement connectors for tension joints from each batch of the material delivered to Site, at least 14 days before fixing of the reinforcement starts, shall be submitted to the Project Manager for review. The number of samples to be provided from each batch shall be as stated in Table 19.1.

(b) The number of specimens in each sample shall be as follows:

(i) bar reinforcement (without epoxy coating or galvanized coating) in accordance with CS2 Table 9
(i) epoxy coated bar reinforcement and galvanized bar reinforcement 2 additional specimens to those specified in CS2 Table 9 for bar reinforcement

(ii) fabric reinforcement (without epoxy coating or galvanized coating) 3

(iii) epoxy coated fabric reinforcement and galvanized fabric reinforcement 4

(iv) reinforcement connectors for tension joints 3

(c) The list of bars currently acceptable for abbreviated testing are given in Construction Standard CS2.

(d) Each specimen of bar reinforcement shall be 1 m long. Each specimen of fabric reinforcement shall be 1.2 m long by 1.2 m wide and shall contain at least three wires in each direction. Each specimen of reinforcement connectors shall consist of one reinforcement connector joined to two lengths of bar each 500 mm long; the bars shall be the same type, size, grade and source of manufacture as the bars to which the reinforcement connector will be fixed in the Permanent Works. The assembly shall be prepared in the same manner as that to be used for the Permanent Works.

(e) Each specimen of bar reinforcement and fabric reinforcement shall be taken from different bars or sheets in the batch. The ends of specimens shall be cut square and loose mill scale and rust shall be removed by wire brushing before delivery to the laboratory.

(f) For epoxy coated bar reinforcement, two additional specimens shall be selected from each batch of reinforcement, as directed by the Project Manager, for epoxy coating tests on thickness, adhesion and continuity in addition to the requirements of tensile tests, bend tests and rebend tests. Each specimen shall be a 2 m length piece cut at least 1m from the ends of a 12 m length bar. Specimens shall be selected from different bundles of the reinforcement batch.

**Table 19.1 : Rate of Sampling of Reinforcement and Reinforcement Connectors for Tension Joints**

<table>
<thead>
<tr>
<th>Description</th>
<th>Size of Batch</th>
<th>No. of samples per batch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar reinforcement</td>
<td>In accordance with Table 9 of CS2</td>
<td></td>
</tr>
<tr>
<td>Fabric reinforcement</td>
<td>0 – 50 tonnes</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>exceeding 50 tonnes</td>
<td>1 for each 50 tonnes or part thereof</td>
</tr>
<tr>
<td>Reinforcement connectors for tension joints</td>
<td>less than 100 No.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>100 – 500 No.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>exceeding 500 No.</td>
<td>3</td>
</tr>
</tbody>
</table>
19.5.3 Testing: Reinforcement

(a) Testing of reinforcement shall be in accordance with Practice Note for Authorized Persons and Registered Structural Engineers No. 122. All verification tests shall be carried out by testing laboratories accredited by HOKLAS.

(b) Each sample of bar reinforcement and fabric reinforcement shall be tested to determine the yield stress, elongation, tensile strength, bending and rebending properties and unit mass. Each sample of fabric reinforcement shall also be tested to determine the weld shear strength. Each sample of epoxy coated reinforcement shall also be tested to determine the thickness, adhesion and continuity of the coating. Each sample of galvanized reinforcement shall also be tested to determine the weight and uniformity of coating.

(c) Each sample of reinforcement connectors for tension joints shall be tested to determine the tensile strength and the slip between the reinforcement connector and the parent bars.

(d) The number of tests on each sample shall be as stated in Table 19.2.

(e) The method of testing shall be in accordance with the following:

<table>
<thead>
<tr>
<th>Material</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hot rolled steel bars</td>
<td>Construction Standard CS2;</td>
</tr>
<tr>
<td>Cold worked steel bars</td>
<td>BS 4461;</td>
</tr>
<tr>
<td>Cold reduced steel wire</td>
<td>BS 4482;</td>
</tr>
<tr>
<td>Steel fabric</td>
<td>BS 4483; and</td>
</tr>
<tr>
<td>Galvanized coating</td>
<td>BS 729.</td>
</tr>
</tbody>
</table>

(f) The method of testing epoxy coatings shall be in accordance with ASTM A775 except that the test for adhesion of coating shall be carried out on 180° bends to design radii in accordance with BS 4466, Table 1. Bends shall be performed at a uniform rate and shall be capable of being completed within 15 seconds without visual distress to the coating.

(g) Tests shall be carried out on specimens having a temperature of between 5°C and 30°C.

19.5.4 Compliance Criteria: Epoxy Coatings to Reinforcement

The results of tests for thickness, adhesion and continuity of epoxy coatings to reinforcement shall comply with the following requirements:

(a) at least 90% of measurements taken to determine the thickness of the coating shall be within the specified limits. The thickness of the coating shall be at least 0.10 mm and shall not exceed 0.30 mm at any point, other than at repaired areas of coating;

(b) cracking or debonding of the coating shall not be visible to the unaided eye on any part of the bent bar; and

(c) the continuity of the coating shall comply with ASTM A775, Clause 7.2.
Table 19.2: Number of Tests on Each Sample of Reinforcement

<table>
<thead>
<tr>
<th>Description</th>
<th>Yield, Elongation and Tensile</th>
<th>Bend</th>
<th>Rebend</th>
<th>Unit Mass</th>
<th>Weld Shear Stress</th>
<th>Thickness, Adhesion and Continuity</th>
<th>Weight and Uniformity of Galvanized Coating</th>
<th>Pitch, Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bar reinforcement</td>
<td>No. of tensile, bend and rebend tests in accordance with CS2 Table 9 and one unit mass test accompanied with each tensile test.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cold reduced steel wire</td>
<td>3 - 1 3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Steel fabric</td>
<td>- - -</td>
<td>3</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>- fabric sheet</td>
<td>-</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>- longitudinal wire</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>- transverse wire</td>
<td>3</td>
<td>-</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Epoxy coating</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Galvanized coating</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>Reinforcement connectors for tension joints</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
</tbody>
</table>

19.5.5 Non-compliance: Characteristic Strength

(a) A batch of bar reinforcement or fabric reinforcement shall be considered as not complying with the specified requirements for characteristic strength if the yield stress in any tensile test carried out on any sample taken from the batch is less than 93% of the specified characteristic strength.

(b) If the yield stress in any tensile test is less than the specified characteristic strength but equal to or greater than 93% of the specified characteristic strength, additional samples shall be provided from the same batch and additional tests for yield stress shall be carried out. The number of samples shall be as stated in Clause 5.1.4 of the Construction Standard CS2. The batch shall be deemed to comply with the Specification if the test specimens meet the requirements of Clause 5.1.2 of the Construction Standard CS2.

(c) The number of specimens in each additional sample shall be seven.

(d) The number of tests on each additional sample of bar reinforcement shall be seven. The number of tests on the longitudinal wires and on the transverse wires of each additional sample of fabric reinforcement shall be seven.

(e) The batch shall be considered as not complying with the specified requirements for characteristic strength if the yield stress in any additional test is less than 93% of the specified characteristic strength.
19.5.6 Non-compliance: Elongation, Tensile Strength, Bending, Rebending, Unit Mass, Weld Shear Strength

If any test specimen fails to meet the tensile strength, elongation, bend or rebend test requirements as stipulated in Construction Standard CS2, two additional test specimens may be taken from different bars of the same batch and be subjected to the test or tests which the original specimen failed. If both additional test specimens pass the retests the batch from which they were taken shall be deemed to comply with this Specification. If either of them fails, the batch shall be deemed not to comply with this Specification.

19.5.7 Non-compliance: Thickness, Adhesion and Continuity of Epoxy Coatings

(a) If the result of any test for thickness, adhesion or continuity of epoxy coatings to reinforcement does not comply with the specified requirements for the property, additional samples shall be provided from the same batch and additional tests for the property shall be carried out. The number of additional samples shall be as stated in Table 19.1.

(b) The number of specimens in each additional sample shall be as follows:

(i) epoxy coated bar reinforcement 4

(ii) epoxy coated fabric reinforcement 2

(c) The number of tests on each additional sample shall be four.

(d) The batch shall be considered as not complying with the specified requirements for the property if the result of any additional test does not comply with the specified requirements for the property.

19.5.8 Non-compliance: Weight and Uniformity of Galvanized Coatings

(a) If the result of any test for weight or uniformity of galvanized coatings to reinforcement does not comply with the specified requirements for the property, additional samples shall be provided from the same batch and additional tests for the property shall be carried out. The number of additional samples shall be as stated in Table 19.1.

(b) The number of specimens in each additional sample shall be as follows:

(i) galvanized bar reinforcement 4

(ii) galvanized fabric reinforcement 2

(c) The number of tests on each additional sample shall be four.

(d) The batch shall be considered as not complying with the specified requirements for the property if the result of any additional test does not comply with the specified requirements for the property.
19.5.9 Compliance Criteria: Reinforcement Connectors for Tension Joints

The results of tensile tests on specimens of reinforcement connectors for tension joints shall comply with the following requirements:

(a) the tensile strength shall not be less than the specified requirements for the parent bar; and

(b) the slip between the reinforcement connector and the parent bars shall not exceed 0.2 mm in 2 minutes at the specified characteristic strength.

19.5.10 Non-compliance: Slip of Reinforcement Connectors

(a) If the result of any test for slip of reinforcement connectors for tension joints does not comply with the specified requirements for slip, additional samples shall be provided from the same batch and additional tests for slip shall be carried out. The number of additional samples shall be as stated in Table 19.1.

(b) The number of specimens in each additional sample shall be six.

(c) The number of tests on each additional sample shall be six.

(d) The batch shall be considered as not complying with the specified requirements for slip if the result of any additional test does not comply with the specified requirements for slip.
[this page not used]
SECTION 20  CONCRETE AND JOINTS IN CONCRETE

20.1     GENERAL

20.1.1     Sprayed Concrete

Sprayed concrete shall comply with Section 8 except as stated in this section.

20.1.2     Joints in Concrete Carriageways

Joints in concrete carriageways shall comply with Section 10.

20.1.3     Movement Joints

Movement joints shall be positioned as shown on the Employer's Drawings and shall comply with this section.

20.1.4     Prestressed Concrete

Prestressed concrete shall comply with Section 21.

20.2     DEFINITIONS & ABBREVIATIONS

20.2.1     Cementitious Content

“Cementitious content” or “cement content” is the mass of cement per cubic metre of compacted concrete or, if cement and PFA are used as separate constituents, the combined mass of cement and PFA per cubic metre of compacted concrete.

20.2.2     Grade

“Grade” is a term used to identify the different concrete mixes in terms of grade strength or in terms of grade strength and nominal maximum aggregate size.

20.2.3     Grade Strength

Grade strength is the compressive strength of concrete stated in the Contract. For designed mix concrete, compliance with the grade strength shall be ascertained in accordance with Clause 20.8.14.

20.2.4     Designation of Concrete Mixes

(a) Designed mix concrete shall be designated by the grade strength in MPa followed by the nominal maximum aggregate size in mm and the suffix D.

(b) Standard mix concrete shall be designated by the grade strength in MPa followed by the nominal maximum aggregate size in mm and the suffix S.

(c) Designed mix concrete or standard mix concrete of the same grade strength but with different constituents, workabilities or other properties shall be designated as such by the addition of a suitable description. If the Grade of concrete is designated by one number only, the number shall be the grade strength in MPa.
(d) Prescribed mix concrete shall be designated by the grade strength in MPa followed by the nominal maximum aggregate size in mm and the suffix P.

20.3 RELEVANT CODES AND STANDARDS

20.3.1 Cement

(a) Cement shall comply with the following:

(i) Ordinary and rapid hardening Portland cement : BS 12:1996

(ii) Sulphate resisting Portland cement : BS 4027

(iii) Portland pulverised-fuel ash cement : BS 6588.

20.3.2 PFA

PFA shall comply with BS 3892:Part 1 except as specified herein.

20.3.3 Aggregates

(a) Fine aggregate shall be clean, hard, durable crushed rock, or natural sand, complying with BS 882 except as specified herein.

(b) Coarse aggregate shall be clean, hard, durable crushed rock complying with BS 882.

20.3.4 Admixtures

(a) Admixtures shall comply with the following:

(i) Pigments for Portland cement and Portland cement products : BS 1014

(ii) Accelerating admixtures, retarding admixtures and water-reducing admixtures : BS 5075:Part 1

(iii) Superplasticising admixtures : BS 5075:Part 3

(iv) Corrosion inhibitor admixtures : BS 5075 Part 1: 1982 or ASTMC-494 Type C

20.4 DESIGN & PERFORMANCE CRITERIA

20.4.1 Concrete Mix

(a) Concrete shall be a designed mix unless the Project Manager reviews without objection the use of a standard or prescribed mix. Designed mixes shall be designed by the Contractor. The Contractor shall select the mix proportions with due regard to workability, strength, durability, temperature control and other requirements stated in the Specifications and on the Employer's Drawings. Prescribed mixes shall be in accordance with the requirements of the Hong Kong Building (Construction) Regulations.
(b) The minimum design slump value for designed mix concrete for reinforced elements, after the addition of superplasticiser if used, shall be as shown in Table 20.1. Should the Contractor wish to use designed mix concrete with a design slump value less than that shown in Table 20.1 in reinforced elements, the Contractor shall submit his proposal to the Project Manager for review to demonstrate that such concrete can be satisfactorily placed and compacted in trial sections simulating the appropriate sections of the Works.

(c) Cement, PFA, aggregates, water and admixtures for concrete shall comply with Clauses 20.5.1 to 20.5.5. All-in aggregate shall not be used.

(d) SRPC shall only be used if stated in the Contract. PFA shall not be used with SRPC.

(e) PFA shall not be used in addition to PPFAC.

(f) Microsilica admixtures shall be used in conjunction with water reducing admixtures.

(g) Corrosion inhibitor admixtures shall be added separately with other admixtures.

Table 20.1 : Workability

<table>
<thead>
<tr>
<th>Degree of Workability</th>
<th>20 mm max. size aggregate</th>
<th>40 mm max. size aggregate</th>
<th>Uses of which Concrete is suitable</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slump (mm)</td>
<td>Slump (mm)</td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>12-25</td>
<td>25-50</td>
<td>Simply reinforced large sections with vibration</td>
</tr>
<tr>
<td>Medium</td>
<td>25-50</td>
<td>50-100</td>
<td>Moderately reinforced sections with vibration, such as ordinary beams and slabs</td>
</tr>
<tr>
<td>High</td>
<td>50-125</td>
<td>100-175</td>
<td>Sections with heavily congested reinforcement where vibration is difficult</td>
</tr>
</tbody>
</table>

20.4.2 Chloride and Sulphate Content of Concrete

(a) The maximum total chloride content of concrete, expressed as a percentage relationship between the chloride ion and the cementitious content by mass in the concrete mix, shall be as stated in Table 20.2. If the concrete is of more than one of the types stated, then the lower value of maximum chloride content shall apply.

(b) The total acid-soluble sulphate content of the concrete mix, expressed as SO₃, shall not exceed 4% SO₃ by weight of the cement in the mix. The sulphate content should be calculated as the various constituents of the mix. The 4% limit does not apply to concrete made with supersulphated cement complying with BS 4248.
Table 20.2: Maximum Total Chloride Content of Concrete

<table>
<thead>
<tr>
<th>Type of concrete</th>
<th>Maximum total chloride content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prestressed concrete. Steam-cured structural concrete</td>
<td>0.1</td>
</tr>
<tr>
<td>Concrete with reinforcement or other embedded metal and made with ordinary or rapid hardening Portland cement.</td>
<td>0.35</td>
</tr>
<tr>
<td>Concrete made with SRPC</td>
<td>0.2</td>
</tr>
</tbody>
</table>

20.4.3 Cementitious Content of Designed Mix Concrete

(a) The minimum cementitious content of designed mix concrete of Grade 20 or above using 20 mm nominal maximum aggregate size shall be as stated in Table 20.3, the minimum cementitious content shall be increased by 40 kg/m³ for 10 mm nominal maximum aggregate size and decreased by 30 kg/m³ for 40 mm nominal maximum aggregate size.

(b) Except as otherwise stated on the Employer's Drawings, the maximum cementitious content of any mix shall be 550 kg/m³ and the maximum cement content of any mix shall be 440 kg/m³.

(c) The maximum cementitious content of designed mix concrete for water retaining structures and watertight structures shall be 400 kg/m³ for concrete containing OPC and shall be 450 kg/m³ for concrete containing either OPC and PFA or PPFAC. The maximum cementitious content of designed mix concrete other than for water retaining structures and water tight structures shall be 550 kg/m³.

(d) The cementitious content of designed mix concrete may be varied during routine production at the discretion of the Contractor by an amount not exceeding 20 kg/m³, provided that the total cementitious content is not less than the specified minimum value and does not exceed the specified maximum value.

(e) When PFA is incorporated in the concrete as a separate material, at least 75% of the specified minimum cementitious content shall be OPC.

(f) The designed free-water/cementitious material ratio of designed mixes shall not exceed:
   (i) 0.40 for concrete of Grade 40 or above;
   (ii) 0.45 for concrete of Grade 30; and
   (iii) 0.60 for concrete below Grade 30.

(g) When microsilica and corrosion inhibitor admixtures are incorporated in the concrete, mixing water used in the designed mix shall be adjusted in accordance with the manufacturer’s recommendations.
For prestressed concrete, the minimum cementitious content shall be 360 kg/m³ for 10 mm nominal maximum aggregate size and 300 kg/m³ for 40 mm nominal maximum aggregate size.

**Table 20.3 : Minimum Cementitious Content of Designed Mix concrete of Grade 20 or Greater with 20mm Nominal Maximum Aggregate Size**

<table>
<thead>
<tr>
<th>Grade strength (MPa)</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum cementitious content (kg/m³)</td>
<td>290</td>
<td>290</td>
<td>310</td>
<td>330</td>
<td>350</td>
<td>375</td>
<td>400</td>
</tr>
</tbody>
</table>

**20.4.4 Standard Mix Concrete**

Standard mix concrete shall comply with the following requirements:

(a) cement shall be OPC or PPFAC;

(b) the total mass of dry aggregate to be used with 100 kg of OPC or with 110 kg of PPFAC shall be as stated in Table 20.4;

(c) the percentage by mass of fine aggregate to total aggregate shall be as stated in Table 20.5; and

(d) admixtures other than water-reducing admixtures shall not be used unless reviewed without objection by the Project Manager.

**Table 20.4 : Mass of Total Aggregate for Standard Mix Concrete**

<table>
<thead>
<tr>
<th>Grade Strength (MPa)</th>
<th>Nominal maximum aggregate size (mm)</th>
<th>40</th>
<th>20</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slump value (mm)</td>
<td>85 – 170</td>
<td>75 – 150</td>
<td>65 – 130</td>
</tr>
<tr>
<td>10</td>
<td>Mass of total aggregate (kg)</td>
<td>800</td>
<td>690</td>
<td>-</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>550</td>
<td>500</td>
<td>400</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>490</td>
<td>440</td>
<td>360</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>440</td>
<td>380</td>
<td>300</td>
</tr>
</tbody>
</table>

**Table 20.5 : Percent by Mass of Fine Aggregate to Total Aggregate for Standard Mix Concrete**

<table>
<thead>
<tr>
<th>Grade strength (MPa)</th>
<th>Grading of fine aggregate (BS 882: Table 5)</th>
<th>Nominal maximum aggregate size (mm)</th>
<th>40</th>
<th>20</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>C, M or F</td>
<td>Percentage by mass</td>
<td>30 - 45</td>
<td>35 - 50</td>
<td>-</td>
</tr>
<tr>
<td>20, 25 or 30</td>
<td>C</td>
<td>of fine aggregate to total aggregate (%)</td>
<td>30 - 40</td>
<td>35 - 45</td>
<td>45 - 55</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td></td>
<td>25 - 35</td>
<td>30 - 40</td>
<td>40 - 50</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td></td>
<td>25 - 30</td>
<td>25 - 35</td>
<td>35 - 45</td>
</tr>
</tbody>
</table>
20.4.5 No-fines Concrete

(a) No-fines concrete shall comply with the following requirements:
   (i) cement shall be OPC or PPFAC;
   (ii) the nominal maximum aggregate size shall be 20 mm; not more than 15% by mass shall be retained on a 20 mm BS test sieve and not more than 10% by mass shall pass a 10 mm BS test sieve;
   (iii) aggregate/cement ratio by mass shall be at least 10 and shall not exceed 15; and
   (iv) the cement content shall be such that each particle of aggregate is coated with cement paste but the compacted concrete has an open texture which permits the flow of water through the hardened concrete.

(b) If the Project Manager requires cubes to be made of the no-fines concrete, these shall be prepared and cured in accordance with the instructions given in BS 1881: Part 113 and shall achieve a strength of 10 MPa when crushed.

(c) No-fines concrete shall be placed with the minimum of punning. No traffic shall be allowed on the finished work and the surface shall be kept clean.

(d) Before placing normal concrete over no-fines concrete a layer of polyethylene sheet of 500 grade or 0.5 mm thickness shall be laid over it and it shall be well lapped to ensure that no mortar from the overlying concrete penetrates to the no-fines concrete.

20.5 MATERIALS

20.5.1 Materials Permitted

(a) The only materials permitted to be used to make concrete are:
   (i) cement;
   (ii) pulverised fuel ash;
   (iii) natural stone aggregates including crushed rock and natural sand;
   (iv) liquid admixtures reviewed without objection by the Project Manager; and
   (v) water.

(b) Exceptionally special additives such as silica fume or ground granulated blast furnace slag may be required to be incorporated in mixes, but if so required this will be specified in the Specification.

(c) All materials used in concrete shall be fully identified and shall be traceable to their sources of extraction or manufacture.

(d) Cement shall comply with the following:
   (i) Ordinary and rapid hardening Portland cement : BS 12 : 1996
(ii) Sulphate resisting Portland cement : BS 4027

(iii) Portland pulverised-fuel ash cement (PPFAC) : BS 6588.

(e) Portland cements having a tricalcium aluminate (C₃A) content for the previous 6 months production, which when calculated according to the procedure given in ASTM-C-150 exceeds either 11.5% for any individual test result or an average value of 11.0% shall not be used.

(f) The PFA content of PPFAC shall not exceed 25% by mass of the PPFAC.

20.5.2 PFA

PFA shall comply with BS 3892:Part 1 except that the criterion for maximum water requirement shall not apply.

20.5.3 Aggregates

(a) Aggregates shall be obtained from a source reviewed without objection by the Project Manager.

(b) Fine aggregate shall be clean, hard, durable crushed rock, or natural sand, complying with BS 882, except that the note in Table 5 of BS 882 shall not apply.

(c) Coarse aggregate shall be clean, hard, durable crushed rock complying with BS 882. The ten percent fines value shall be at least 100 kN. The water absorption shall not exceed 0.8%. The flakiness index shall not exceed 35%.

20.5.4 Water

(a) Water for concrete and for curing concrete shall be clean, uncontaminated and from a source reviewed without objection by the Project Manager. The Contractor shall test water proposed to be used to produce concrete in accordance with the requirements of Clause 20.8.3.

(b) The use of recycled water for concrete is not permitted.

20.5.5 Admixtures

(a) Admixtures will normally only be permitted if they are liquids and they shall be measured by volume or weight. If the Project Manager has reviewed without objection the use of a solid or paste admixture this shall be thoroughly dispersed or dissolved in at least 10 times its weight of water so that it will be distributed uniformly in the concrete before any concrete is placed. The water used for dispersing the admixture shall be considered as part of the mixing water in the concrete and shall be included in the calculation of the water/cement ratio of the concrete.

(b) Admixtures shall comply with the following:

(i) Pigments for Portland cement and Portland cement products : BS 1014

(ii) Accelerating admixtures, retarding admixtures and water-reducing admixtures : BS 5075:Part 1
(iii) Superplasticising admixtures : BS 5075:Part 3

(iv) Corrosion inhibitor admixtures : BS 5075:Part 1 : 1982 or ASTM C-494 Type C

(c) The chloride ion content of admixtures for concrete containing embedded metal or for concrete made with SRPC shall not exceed 2% by mass of the admixture or 0.03% by mass of the cementitious content, whichever is less.

20.5.6 Curing Compound

(a) Curing compounds shall be a proprietary type reviewed without objection by the Project Manager and shall have an efficiency index of at least 80%.

(b) Curing compounds shall contain a fugitive dye. Curing compounds containing organic solvents shall not be used. The curing compound shall become stable and achieve the specified resistance to evaporation of water from the concrete surface within 60 minutes after application. Curing compounds shall not react chemically with the concrete to be cured and shall not crack, peal or disintegrate within one week after application. Curing compounds shall degrade completely within three weeks after application and the concrete surface so treated shall not impair the bonding of applied finishes.

(c) Curing compounds for use on concrete surfaces against which potable or fresh water will be stored or conveyed shall be non-toxic and shall not impart a taste to the water.

20.5.7 Materials for Joints in Water Retaining Structures and Water Tight Structures

(a) Materials for joints in water retaining structures and water tight structures for sewage shall be resistant to aerobic and anaerobic bacteriological attack and to attack by petrol, diesel oil, dilute acids and alkalis.

(b) Materials for joints in water retaining structures for potable and fresh water shall be non-toxic and shall not impart taste and colour to the water.

20.5.8 Joint Filler

Joint filler shall be a proprietary type reviewed without objection by the Project Manager and shall be a firm, compressible, single-thickness, non-rotting filler. Joint filler for joints in water retaining structures and watertight structures shall be non-absorbent.

20.5.9 Bitumen Emulsion

Bitumen emulsion for joints in water retaining structures and watertight structures shall comply with BS 3416. Bitumen emulsion for surfaces against which potable or fresh water will be stored or conveyed shall comply with BS 3416, Type II.

20.5.10 Joint Sealant

(a) Joint sealant shall be a grade suited to the climatic conditions of Hong Kong and shall perform effectively over a temperature range of 0°C to 60°C. The colour of all sealants in exposed areas shall be reviewed without objection by the Project Manager. Joint sealant for exposed joints in water retaining structures shall be grey.
(b) Joint sealant other than cold-applied bitumen rubber sealant shall be:

(i) a gun grade for horizontal joints 15 mm wide or less and for vertical and inclined joints; and

(ii) a pouring grade for horizontal joints wider than 15 mm.

(c) Polysulphide-based sealant shall be a cold-applied two-part sealant complying with BS 4254. Polysulphide-based sealant for expansion joints in water retaining structures shall have a transverse butt-joint movement range of at least 20%.

(d) Polyurethane-based sealant shall be a cold-applied two-part sealant complying with the performance requirements of BS 4254.

(e) Hot-applied bitumen rubber sealant shall comply with BS 2499, Type A1.

(f) Cold-applied bitumen rubber sealant shall be a proprietary type reviewed without objection by the Project Manager.

(g) Joint sealant for joints in water retaining structures and watertight structures shall be as stated in Table 20.6.

(h) Primers and caulking material for use with joint sealant shall be a proprietary type recommended by the joint sealant manufacturer and reviewed without objection by the Project Manager.

(i) Different types of joint sealant and primers which will be in contact, shall be demonstrated as being compatible.

### Table 20.6: Joint Sealant for Water Retaining Structures and Water Tight Structures

<table>
<thead>
<tr>
<th>Type of water retaining structure</th>
<th>Type of joint</th>
<th>Type of joint sealant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage</td>
<td>All joints</td>
<td>Polyurethane-based</td>
</tr>
<tr>
<td>Other than sewage</td>
<td>Expansion joints</td>
<td>Polysulphide-based</td>
</tr>
<tr>
<td></td>
<td>Horizontal joints other than expansion joints</td>
<td>Hot-applied bitumen rubber</td>
</tr>
<tr>
<td></td>
<td>Vertical and inclined joints other than expansion joints</td>
<td>Polysulphide-based or cold-applied bitumen rubber</td>
</tr>
</tbody>
</table>

#### 20.5.11 Bond Breaker Tape

Bond breaker tape shall be a proprietary type recommended by the joint sealant manufacturer and reviewed without objection by the Project Manager. The tape shall be a polyethylene film with adhesive applied on one side and shall be the full width of the groove.
20.5.12 Strip and Pad Bearings

(a) Strip bearings shall be used where specified on the Employer's Drawings. The preferred type of bearings shall consist of a polished stainless steel sliding against a P.T.F.E. coated natural rubber strip blocked out either side with expanded polystyrene spacer strips. Bearings shall be continuous over the length of joint as indicated on the Employer's Drawings. Other proprietary types of strip bearings may be submitted for review by the Project Manager.

(b) Pad bearings shall be used where specified on the Employer's Drawings. The preferred type of bearings shall consist of a stainless steel top plate roughened on the upper surface and polished on the lower, sliding against a P.T.F.E. coated natural rubber/reinforced rubber pad, blocked out all around with expanded polystyrene spacer blocks. Bearings shall be placed at the centres indicated on the Employer's Drawings. Other proprietary types of pad bearings may be submitted for review by the Project Manager.

20.5.13 Waterstops

(a) Waterstops, including intersections, reducers and junctions, shall be a proprietary type reviewed without objection by the Project Manager, or as shown on the Employer's Drawings and shall be natural or synthetic rubber or extruded polyvinyl chloride with the properties stated in Table 20.7.

(b) Unless otherwise stated on the Employer's Drawings, the size of waterstops shall be as follows:

<table>
<thead>
<tr>
<th>Wall or Slab Thickness (mm)</th>
<th>Waterstop Size (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≥ 250</td>
<td>250</td>
</tr>
<tr>
<td>200 - 250</td>
<td>200</td>
</tr>
<tr>
<td>&lt; 200</td>
<td>150</td>
</tr>
</tbody>
</table>

(c) Hydrophilic waterstops shall be installed where shown on the Employer's Drawings. They shall be made from a preformed elastomeric strip which can integrate into existing waterstop networks and shall be free from rubber, bentonite or other inclusions. The waterstop shall have an unrestrained volumetric expansion of not less than 170% and must not deteriorate under prolonged wet/dry cycling and must be able to withstand a hydrostatic head of 50 m. The waterstop shall be installed in accordance with the manufacturer's instructions.

Table 20.7: Properties of Waterstops

<table>
<thead>
<tr>
<th>Property</th>
<th>Rubber waterstops</th>
<th>PVC waterstops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>1100 kg/m³ (± 5%)</td>
<td>1300 kg/m³ (± 5%)</td>
</tr>
<tr>
<td>Hardness</td>
<td>60 - 70 IRHD</td>
<td>70 - 90 IRHD</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>≥ 20 N/mm²</td>
<td>≥ 13 N/mm²</td>
</tr>
<tr>
<td>Elongation at break point</td>
<td>≥ 450%</td>
<td>≥ 285%</td>
</tr>
<tr>
<td>Water absorption</td>
<td>≤ 5% by mass after 48 hours immersion</td>
<td>≤ 0.15% by mass after 24 hours immersion</td>
</tr>
<tr>
<td>Softness number</td>
<td>-</td>
<td>42 – 52</td>
</tr>
</tbody>
</table>
20.6  SUBMISSIONS

20.6.1  Particulars of  Materials for Concrete

(a) The following particulars of the proposed cement, PFA and aggregates shall be submitted to the Project Manager for review:

(i) a certificate applicable to the material to be supplied and not older than 6 months for each type of cement showing the manufacturer's name, the date and place of manufacture and showing that the cement complies with the requirements stated in the Contract and including results of tests for:

- chemical composition;
- fineness;
- compressive strength at 3, 7 and 28 days;
- initial and final setting times;
- soundness; and
- proportion by mass of PFA contained in PPFAC.

(ii) a certificate applicable to the material to be supplied and not older than 6 months for PFA showing the source of the PFA and showing that the PFA complies with the requirements stated in the Contract and including results of tests for:

- chemical composition;
- fineness; and
- moisture content.

(iii) a certificate applicable to the material to be supplied and not older than 6 months for each nominal maximum aggregate size showing the source of the aggregate and showing that the aggregate complies with the requirements stated in the Contract and including results of tests for:

- grading;
- silt content;
- chloride content;
- flakiness index of coarse aggregate;
- ten percent fines value; and
- water absorption.

(b) The following particulars of the proposed admixtures shall be submitted to the Project Manager for review:

(i) manufacturers' literature;

(ii) description of physical state, colour and composition;

(iii) recommended storage conditions and shelf life;

(iv) method of adding to the concrete mix;

(v) any known incompatibility with other admixtures or cement;

(vi) recommended dosage;
(vii) effects of under-dosage and over-dosage; and

(viii) a certificate which is applicable to the material to be supplied and not older than 6 months for each type of admixture showing the manufacturer's name, the date and place of manufacture and showing that the admixture complies with the requirements stated in the Contract and including results of tests for:

- uniformity;
- chloride content; and
- details of toxicity.

(c) The following particulars of the proposed curing compound shall be submitted to the Project Manager for review:

(i) manufacturer's literature;

(ii) description of physical state, colour and composition;

(iii) recommended storage conditions and shelf life;

(iv) method of application;

(v) recommended rate of application; and

(vi) a certificate showing the manufacturer's name, the date and place of manufacture and showing that the curing compound complies with the requirements stated in the Contract and including results of tests for efficiency index.

20.6.2 Particulars of Concrete Mix

(a) The following particulars of each proposed designed concrete mix shall be submitted to the Project Manager for review:

(i) quantity of each constituent per batch and per cubic metre of compacted concrete, with required tolerances on quantities of aggregates to allow for minor variations in grading, silt content etc. The maximum permitted variation in the quantity of fine aggregate shall be ± 20 kg of fine aggregate per 100 kg of cement;

(ii) type and source of cement and PFA;

(iii) type and quantity of admixture;

(iv) the type and source of fine and coarse aggregates;

(v) grading details in tabular and graphical form of coarse and fine aggregates, including combined grading curves; and

(vi) grading details, in tabular and graphical form, of the combined aggregates, together with details of the proportions in which the fine and coarse aggregates are to be combined;

(vii) workability in terms of designed slump value before and after the addition of superplasticisers;
(viii) method of placing concrete;

(ix) method of controlling the temperature of the concrete, if required;

(x) test or trial mix data for designed mix concrete of the same Grade and with similar constituents and properties, if available;

(xi) test data for designed mix concrete of the same or other grade produced in the plant or plants proposed to be used, if available; and

(xii) total chloride ion content of the mix.

20.6.3 Particulars of Ready-mixed Concrete Supplier

(a) The name of the suppliers and the location of each plant, including a back-up plant, from which the Contractor proposes to obtain ready-mixed concrete shall be submitted to the Project Manager at least 14 days before trial mixes are made or, if trial mixes are not required, at least 30 days before the ready-mixed concrete is programmed to be placed in the Permanent Works.

(b) The plant producing the concrete shall be operated in accordance with the Quality Scheme for the Production and Supply of Concrete (QSPSC) of the Hong Kong Quality Assurance Agency (HKQAA).

(c) Ready mix concrete shall be as defined in BS 5328.

20.6.4 Particulars of Batching and Mixing Plant

Particulars of the proposed batching and mixing plant to be used on Site, including a layout plan and the output of the plant, shall be submitted to the Project Manager for review at least 28 days before the plant is delivered to Site.

20.6.5 Particulars of Precast Concrete Units

(a) The method of manufacture of precast concrete units on or off Site shall be reviewed without objection by the Project Manager before work commences. No changes shall be made thereafter without prior review without objection by the Project Manager.

(b) The following particulars of the proposed precast concrete units shall be submitted to the Project Manager for review:

(i) Contractor’s Drawings showing the full details of the elements including dimensions, fixings, lifting points, reinforcement and chases;

(ii) method of manufacture which must include details of:

- place of manufacture;
- proposed formwork systems and materials;
- method of placing and compacting concrete;
- method of curing concrete;
- proposed quality control procedures; and
- details of lifting points and methods of handling;

(iii) date of commencement of manufacture and casting of each type of member;
(iv) details of precasting yards;

(v) procedure for testing precast units;

(vi) not more than seven days after the transfer of stress, a certificate showing the force and extension in the tendons after anchorage, the strength and age of the test cubes cast as described in this section and the minimum age in hours of the concrete at the time the stress was applied to the member; and

(vii) a certificate showing the manufacturer's name, the date and place of manufacture, the identification number of the precast concrete units and including results of tests for:

- compressive strength of concrete cubes at 28 days; and
- routine tests, including loading tests, carried out at the precast yard;

(c) The following particulars of the constructed precast concrete units shall be submitted to the Project Manager for onward submission to the Buildings Department:

(i) the date and place of manufacture, the identification numbers of the precast concrete units and including results of tests for compressive strength of concrete cubes at 28 days tested by a HOKLAS accredited testing laboratory;

(ii) a detailed method statement including the design, drawings and installation procedures for all the temporary support works for erection of the precast concrete elements;

(iii) the names and qualifications of the supervisory personnel supervising the fabrication, erection and examination of the precast concrete units; and

(iv) a copy of the site log book recording the date and time of inspections and details of Site activities.

20.6.6 Particulars of Construction Joints

Particulars of the proposed positions and details of construction joints in concrete shall be submitted to the Project Manager for review. This submission shall include details of any material which is to remain permanently in the Works as part of forming the joint.

20.6.7 Particulars of AAR in Concrete

(a) The following particulars of the proposed concrete mix shall be submitted to the Project Manager for review:

(i) HOKLAS endorsed test certificates not older than 6 months giving the results of tests required in Section 20.8.4(c)(ii) to (vi); and

(ii) calculation of the reactive alkali of the proposed mix.

(b) New HOKLAS endorsed test certificates giving the results of tests required in Section 20.8.4(c)(ii) to (vi) shall be submitted at quarterly intervals together with any necessary further calculations to demonstrate that the mix continues to comply with the limit on reactive alkali.
20.6.8 Trial Mix Concrete

(a) Trial mixes are not required for designed mix concrete of Grade 20 and below, for standard mix concrete or for prescribed mix concrete.

(b) If test data for designed mix concrete of the proposed Grade and with similar constituents and properties and produced in the plant or plants proposed to be used are submitted in accordance with Section 20.6.2, and are reviewed without objection by the Project Manager, no trials for that designed mix will be required.

(c) If test data for designed mix concrete of the proposed Grade and with similar constituents and properties produced in plant other than that proposed to be used are submitted in accordance with Section 20.6.2, and are reviewed without objection by the Project Manager, the Project Manager may require plant trials to be carried out in accordance with Section 20.6.9.

(d) If test data for designed mix concrete produced in the plant or plants proposed to be used, but of a Grade or with constituents and properties other than those proposed, are submitted in accordance with Section 20.6.2, and are reviewed without objection by the Project Manager, the Project Manager may require laboratory mix trials to be carried out in accordance with Section 20.6.10.

(e) If no test data for designed mix concrete are submitted or if test data submitted in accordance with Section 20.6.2 does not in the opinion of the Project Manager demonstrate the suitability of the proposed plant and mix design, the Project Manager may require both plant trials and laboratory mix trials to be carried out in accordance with Sections 20.6.9 and 20.6.10 respectively.

(f) Plant trials and laboratory mix trials shall be completed at least 35 days before the concrete mix is programmed to be placed in the Permanent Works.

(g) The Contractor shall notify the Project Manager before conducting plant trials or laboratory mix trials.

20.6.9 Plant Trials

(a) Plant trials shall be made using the plant or plants proposed and the mix designs and constituents submitted to and reviewed without objection by the Project Manager.

(b) One batch of concrete of a proposed designed mix shall be made on each of three days in each plant proposed to be used. The batch shall be at least 60% of the mixer's nominal capacity. If the concrete is batched in a central plant and mixed in a truck mixer, three different truck mixers shall be used.

(c) Three samples of concrete shall be provided from each batch at approximately 1/6, 1/2 and 5/6 of the discharge from the mixer. Each sample shall be of sufficient size to perform a slump test and make two 150 mm test cubes. The method of sampling shall be as stated in CS1.

(d) Each sample taken in accordance with Section 20.6.9(c) shall be tested to determine its slump value in accordance with CS1.

(e) Two 150 mm test cubes shall be made from each of the three samples taken in accordance with Section 20.6.9(c) and stored, cured and tested to determine the compressive strength at 28 days in accordance with CS1.
20.6.10 Laboratory Mix Trials

(a) Laboratory mix trials shall be made in the Contractor's laboratory using the mix designs and constituents submitted to and reviewed without objection by the Project Manager.

(b) Laboratory mix trials shall be carried out in accordance with Section 11 of CS1. Three separate batches shall be made, each of sufficient size to provide samples for two slump tests and to make six 150 mm test cubes.

(c) Two slump tests in accordance with CS1 shall be performed on separate specimens from each batch of laboratory trial mix concrete.

(d) Six 150 mm test cubes shall be made from each batch of laboratory trial mix concrete, stored, cured and tested for compressive strength at 28 days in accordance with CS1.

20.6.11 Compliance Criteria: Plant trials

(a) The results of tests on concrete taken from plant trials in accordance with Section 20.6.9 shall comply with the following requirements:

(i) the average of the three slump values shall be within 20 mm or 25%, whichever is the greater, of the designed slump value;

(ii) the range of the three slump values for each batch of concrete shall not exceed 20% of the average of the three slump values for that batch;

(iii) the average compressive strength at 28 days of the 6 test cubes shall exceed the Grade strength by at least 10 MPa and the compressive strength of each individual test cube shall exceed the Grade strength by at least 4 MPa; and

(iv) the range of the compressive strength of the six test cubes from each batch of concrete shall not exceed 20% of the average compressive strength of the six test cubes from that batch.

20.6.12 Compliance Criteria: Laboratory Mix Trials

(a) When test data relating to the proposed plant or plants submitted in accordance with Section 20.6.2 show that the plant standard deviation exceeds 5 MPa, or in the absence of acceptable data, the results of tests on laboratory trial mix concrete shall comply with the following requirements:

(i) the average of the six slump values shall be within 20 mm or 25%, whichever is the greater, of the design slump value; and

(ii) the average compressive strength at 28 days of the 18 test cubes shall exceed the Grade strength by at least 12 MPa and the compressive strength of each individual test cube shall exceed the Grade strength by at least 6 MPa.

(b) When test data relating to the proposed plant or plants submitted in accordance with Section 20.6.2 show that the plant standard deviation does not exceed 5 MPa, the results of tests on laboratory mix trial concrete shall comply with the following requirements:

(i) the average of the six slump values shall be within 20 mm or 25%, whichever is the greater, of the design slump value; and
the average compressive strength at 28 days of the 18 test cubes shall exceed the Grade strength by at least 8 MPa and the compressive strength of each individual test cube shall exceed the Grade strength by at least 2 MPa.

20.6.13 Trial Lengths and Trial Panels

Trial lengths required in accordance with Sections 10.5.2 to 10.5.5 and trial panels required in accordance with Sections 18.5.2 and 18.5.3 shall be constructed for each concrete mix as appropriate.

20.6.14 Non-compliance: Trial Mix Concrete

(a) If the result of any test for workability or compressive strength of laboratory mix trial and plant trial concrete does not comply with the specified requirements for the property, particulars of proposed changes to the materials, mix design or methods of production shall be submitted to the Project Manager for review. Further laboratory mix trials or plant trials shall be made until the result of every test complies with the specified requirements for workability and compressive strength of laboratory mix trial and plant trial concrete.

(b) If trial lengths or trial panels are constructed using the non-complying trial mix, further trial lengths or trial panels shall be constructed.

20.6.15 Acceptable Concrete Mix

(a) A concrete mix which complies with the specified requirements for laboratory mix trials, plant trials and for trial lengths or trial panels is defined as an "Acceptable Concrete Mix". The designed slump value used to produce an "Acceptable Concrete Mix" shall become the "Acceptable Slump Value".

(b) If laboratory mix trials or plant trials are not required, a concrete mix submitted as stated in Section 20.6.12 and which complies with the specified requirements for trial lengths or trial panels shall become an "Acceptable Concrete Mix". The designed slump value of the concrete mix shall become the "Acceptable Slump Value".

20.6.16 Records of Concrete

(a) Each delivery of concrete to Site shall be accompanied by a certificate giving full details of its origin and composition. The weights of materials in each batch of concrete shall be recorded automatically by the batching equipment and the printed records shall be available to the Project Manager for inspection at all times. Manually prepared records of batch composition are not acceptable. Delivery notes shall contain the following details:

(i) serial number of delivery note;
(ii) date and time of loading;
(iii) name and location of batching and mixing plant;
(iv) registration number of delivery vehicle;
(v) name of purchaser;
(vi) name and location of the Site;

(vii) designation of concrete mix and "Acceptable Slump Value";

(viii) type name and quantity of admixture;

(ix) quantity of concrete;

(x) quantity of water in litres per cubic metre of concrete and the time of introduction of water to the concrete;

(xi) moisture content of fine aggregate and amount of water subtracted from the batch quantities to compensate for this;

(xii) type of cementitious material, weight in kilograms per cubic metre of concrete and time of introduction to the concrete mix; and

(xiii) type of aggregate and weights of fine and coarse aggregates in kilograms per cubic metre of concrete.

(b) Records of concreting operations shall be kept by the Contractor on Site. Records shall contain the following details:

(i) date;

(ii) designation of concrete mix and "Acceptable Slump Value";

(iii) total quantity of each concrete mix produced that day;

(iv) serial number of delivery note;

(v) arrival time of delivery vehicle;

(vi) time of completion of discharge;

(vii) position where concrete was placed;

(viii) results of slump tests;

(ix) details of test cubes made; and

(x) temperature of concrete.

(c) The Contractor shall submit to the Project Manager for review a statement covering the method of placing concreting at any one location. The statement shall cover all items of plant to be used and their respective layout and shall include the extent of bays, sequence of concreting and proposals for stop ends. With respect to concrete temperature, the Contractor shall submit to the Project Manager for review a detailed method statement of his proposed temperature control and monitoring strategy and the substantiation of this strategy. The information to be submitted shall include, but shall not be limited to, the following:

(i) concrete mix details including heat of hydration and specific heat characteristics of the proposed constituents;

(ii) formwork type and insulation;
(iii) curing details related to temperature effects; and

(iv) calculations of the forecast concrete temperature, temperature gradients and resulting stresses. The calculation of temperature in concrete shall be in accordance with the Construction Industry Research and Information Association Report No. 91, "Early Age Thermal Crack Control in Concrete"

20.6.17 Particulars of Materials for Joints

(a) The following particulars of the proposed materials for joints shall be submitted to the Project Manager for review:

(i) manufacturer's literature and a certificate for joint filler showing the manufacturer's name, the date and place of manufacture and showing that the joint filler complies with the requirements stated in the Contract and including results of tests for:
   - disintegration and shrinkage;
   - recovery value and reduction in mass; and
   - extrusion;

(ii) manufacturer's literature and a certificate for bitumen emulsion showing the manufacturer's name, the date and place of manufacture and showing that the bitumen emulsion complies with the Specification;

(iii) manufacturer's literature for joint sealant, including details of the method and time required for mixing the different components, and a certificate showing the manufacturer's name, the date and place of manufacture and showing that the sealant complies with the Specification and including results of tests as appropriate for:
   - rheological properties;
   - plastic deformation;
   - adhesion and tensile modulus;
   - application life;
   - adhesion in peel;
   - loss of mass after heat ageing;
   - staining;
   - transverse butt joint movement range;
   - extension;
   - flow;
   - penetration;
   - degradation; and
   - fire rating, where appropriate;

(iv) manufacturer's literature and a certificate for strip and pad bearings for sliding joints showing the manufacturer's name, the date and place of manufacture and showing that the strips comply with the Specification and including results of tests for:
   - vertical load;
   - coefficient of friction; and
   - a description of the method of installation of bearings;
(v) manufacturer's literature for waterstops, including details of intersections, reducers and junctions, and a certificate showing the manufacturer's name, the date and place of manufacture and showing that the waterstops comply with the requirements stated in the Contract and including results of tests for:

- density;
- hardness;
- tensile strength;
- elongation at break point;
- water absorption;
- softness number of PVC waterstops; and
- hydrophilic properties, where appropriate; and

(vi) particulars of primers and caulking material for joint sealant and of bond breaker tape.

20.6.18 Representative Samples of Materials

(a) Representative samples of the following proposed materials shall be submitted to the Project Manager at the same time as particulars of the material are submitted:

(i) joint filler and joint sealant;
(ii) bond breaker tape;
(iii) bearing strip for sliding joints; and
(iv) waterstops, including intersections, reducers and junctions.

20.7 WORKMANSHP

20.7.1 Storage of Cement and PFA

(a) Cement in bags shall be stored in a dry, weatherproof store with a raised floor. Each delivery shall be identified and kept separate and shall be used in the order of delivery.

(b) Bulk cement and PFA shall be stored in dry, weatherproof silos. Cement and PFA of different types and from different sources shall be stored in separate silos clearly marked to identify the different contents of each.

(c) The loading, unloading, transfer, handling or storage of bulk cement or dry PFA during or after the debagging process must be done in a totally enclosed system or facility. Any vent or exhaust shall be fitted with fabric filter or equivalent air pollution control system or equipment.

20.7.2 Handling and Storage of Aggregates

(a) Aggregates shall not be handled or stored in a manner which will result in mixing of the different types and sizes or in segregation or contamination of the aggregates.

(b) Different types and sizes of aggregates shall be stored in separate hoppers or in separate stockpiles. The stockpiles shall have well drained concrete floors and shall have dividing walls of sufficient height to keep the different aggregates separate.
20.7.3 **Storage of Admixtures and Curing Compounds**

Admixtures and curing compounds shall be stored in sealed containers marked to identify the contents and protected from exposure to conditions which may affect the material. The materials shall be stored in accordance with the manufacturers' recommendations and shall not be used after the recommended shelf life has been exceeded.

20.7.4 **Handling and Storage of Precast Concrete Units**

(a) The identification number, date of casting and lifting points shall be marked on precast concrete units in a manner reviewed without objection by the Project Manager.

(b) Precast concrete units shall be lifted and supported only at the designed lifting points and shall not be subjected to rough handling, shock loading or dropping.

(c) Precast concrete units shall be stored off the ground on level supports and in a manner which will not result in damage or deformation to the units or in contamination of the units. Precast concrete units shall be protected from damage and damaged units shall not be used in the Permanent Works.

(d) At all stages of construction, precast concrete units and other associated concrete shall be adequately protected to prevent damage to permanently exposed concrete surfaces, particularly any decorative features.

(e) Precast units shall not to be lifted until at least 24 hours after casting or until concrete has attained a strength adequate to resist the resultant stresses without inducing cracking or other damage to the concrete.

20.7.5 **Batching Concrete**

(a) Concrete shall be produced at a plant certified, registered and operated in accordance with the Quality Scheme for the Production and Supply of Concrete (QSPSC) of the Hong Kong Quality Assurance Agency (HKQAA). The requirements of the Specification shall prevail over those of the QSPSC.

(b) Measuring and weighing equipment for batching concrete shall be maintained in a clean, serviceable condition and their accuracy shall be maintained within the tolerances given in BS 1305. The equipment shall be checked regularly at intervals reviewed without objection by the Project Manager and at a minimum in accordance with the requirements of Appendix A20.4, Part 1. The accuracy of the measuring equipment shall be within 3% of the quantity of cementitious materials, total aggregates or water being measured and within 5% of the quantity of admixtures being measured.

(c) The quantities of cement, PFA and fine and coarse aggregates shall be measured by mass except that cement supplied in bags may be measured by using a whole number of bags in each batch. The mass of aggregates shall be adjusted to allow for the free moisture content of the aggregates.

(d) Separate weighing equipment shall be used for cementitious material and aggregates.
(e) The quantity of water shall be adjusted for the free moisture content of the aggregates and shall be measured by mass or volume.

(f) Liquid admixtures shall be measured by mass or volume and powdered admixtures shall be measured by mass.

20.7.6 Mixing Concrete

(a) The quantities of concrete mixed and the speed of operation of a mixer shall comply with the manufacturer's recommendations.

(b) A mixer shall not be loaded in excess of its rated capacity and shall be emptied before being re-charged. A mixer which has been out of use for more than 30 minutes shall be cleaned before fresh concrete is mixed in it. Mixers shall be cleaned whenever there is a change in the type of cement being used.

(c) Mixing times or the number and rate of revolutions of mixer drums shall be in accordance with the recommendations of the manufacturer unless the Contractor can demonstrate otherwise. Constituents shall be thoroughly mixed and admixtures shall be uniformly distributed throughout the concrete.

(d) Water shall be added to truck mixed concrete at the batching plant and shall not be added in transit or be added at Site.

(e) Superplasticising admixtures used with concrete mixed off Site shall be added at Site.

(f) Water shall not be added to partially hardened concrete.

(g) Partially hardened concrete shall not be remixed, with or without additional cement, aggregate or water.

20.7.7 Transportation of Concrete

(a) Concrete shall not be transported in a manner which will result in contamination, segregation, loss of constituents or excessive evaporation.

(b) Concrete batched off Site shall be transported to Site in purpose-made agitators operating continuously.

(c) Where an agitator is used for transporting concrete, the discharge shall be completed within a period reviewed without objection the Project Manager. The time of contact between cement and water shall be deemed to be the loading time recorded on the delivery ticket.

(d) Where concrete is transported in non-agitating equipment, discharge shall be completed within a period reviewed without objection the Project Manager. The time at which mixing was completed shall be deemed to be the loading time recorded on the delivery ticket.

(e) Transportation equipment shall be checked regularly at intervals reviewed without objection by the Project Manager in accordance with the requirements of Appendix A20.4, Part 2.
20.7.8 Commencement of Concreting

Concrete shall not be placed in the Permanent Works until the concrete mix has been reviewed without objection by the Project Manager.

20.7.9 Changes in Materials and Methods of Construction

The materials, mix design, methods of production or methods of construction used to produce an "Acceptable Concrete Mix" shall not be changed except that the variations of cement content as stated in Section 20.4.3(d), and variations in aggregate quantities within the permitted tolerances, will be allowed.

20.7.10 Concrete Placing and Temperature

(a) The Contractor shall notify the Project Manager before concrete is placed in any part of the Permanent Works, allowing sufficient time for the Project Manager to inspect the works which are to be concreted.

(b) Concrete shall be compacted in its final position within 1 hour of discharge from the mixer unless carried in purpose made agitators, operating continuously, when the time shall be within 2½ hours of the introduction of cement to the mix and within 30 minutes of discharge from the agitator.

(c) Concrete which does not satisfy the compliance criteria for workability as stated in Section 20.8.9 shall not be placed in the Permanent Works.

(d) Where it is necessary to deposit concrete under water, details of the methods, equipment, materials and proportions of the mixes to be used shall be submitted to the Project Manager for review before the work is commenced. Where the concrete is placed by a tremie, its size and method of operation shall be in accordance with BS 8004. During and after concreting under water, pumping or dewatering operations in the immediate vicinity shall be suspended for a period which has been reviewed without objection by the Project Manager.

(e) All formwork and reinforcement contained within it shall be clean and free from standing water immediately before the placing of the concrete.

(f) Concrete shall be placed as close as practicable to its final position and shall not be moved into place by vibration. Trunking or chutes shall be used to place concrete which would otherwise fall more than 2.0 m. When trunking or chutes are used they shall be kept clean and used in such a way as to avoid segregation.

(g) Concrete shall be placed in such a manner that the formwork, reinforcement or built-in components are not displaced.

(h) Concrete unless placed by tremie, shall be placed in horizontal layers to a compacted depth of not more than 450 mm if internal vibrators are used and to a compacted depth of not more than 150 mm in other cases.

(i) Concrete shall be placed continuously within the element to be concreted. Fresh concrete shall not be placed against concrete which has been in position for more than 30 minutes. Otherwise a construction joint shall be formed as stated in Section 20.7.14.

(j) Concrete shall not be placed in ground or water which has a temperature below 5°C.
(k) Where the ambient temperature is greater than 32°C full hot weather concreting techniques as described in ACI document ACI 305R-89, Clauses 3.1, 3.2, 3.3, 3.4, 3.5, 3.6, 4.1, 4.2 and 4.3 shall be implemented.

(l) No concrete shall be placed in free-flowing water. Cofferdams or forms shall be sufficiently tight to reduce the flow or current of water through the space where the concrete is to be deposited to a velocity or flow rate, reviewed without objection by the Project Manager. Cofferdams or forms in still water shall be sufficiently tight to prevent loss of mortar through the walls.

(m) Before concrete is placed on a rock foundation the rock surface shall be clean and free from soft rock and loose rock, dust or other debris. The final cleaning shall be done with air and/or water jets and excavation with hand held tools.

(n) After the rock surface has been prepared and reviewed without objection by the Project Manager and immediately before placing blinding or other concrete, the surface of the rock shall be covered with a layer of grout 6 mm thick. The grout shall have the consistency of a stiff paste and it shall be well brushed over the rock and into all crevices.

(o) The temperature of concrete at the time of placing shall be measured and controlled. The Contractor shall take measures to ensure that after placing, the maximum temperature attained in the concrete and the temperature gradient does not exceed specified levels.

(p) The temperature of concrete at the time of placing in the forms shall not be more than 32°C. The Contractor shall submit details of the proposed measures to ensure that this temperature will not be exceeded.

(q) The temperature shall be measured by placing a calibrated probe-type thermometer into the concrete at the time of discharge from the vehicle transporting it or not later than 15 minutes thereafter.

(r) The Contractor shall employ effective means such as pre-cooling the aggregates and mixing water, as necessary, to maintain the temperature of the concrete below 32°C prior to placing.

(s) After concrete has been placed its temperature shall not be permitted to rise above 70°C.

(t) The maximum temperature gradient within any structure due to heat of hydration taken at any two points one metre apart shall not exceed 15°C. Irrespective of the thickness of a section the maximum temperature differential between the core and the surface shall not exceed 20°C overall.

20.7.11 Placing Concrete by Pumping

(a) Concrete pumps shall be operated and maintained in accordance with the manufacturer's recommendations. The pumps and pipelines shall be maintained in a clean condition. Internal surfaces of pipelines shall not be aluminum. Joints in pipelines shall not permit grout loss.

(b) Concrete pumps shall be positioned such that pipelines are as short and straight as practicable and require as little repositioning as practicable. Bends in pipelines shall be arranged in such a manner that the concrete, formwork, reinforcement or built-in components are not disturbed.
20.7.12 Placing Concrete by Tremie

(a) Tremies used to place concrete shall be securely supported in position and the joints shall be watertight. A temporary seal of a type reviewed without objection by the Project Manager shall be used to keep the water and the concrete separate at the start of concreting.

(b) After the concrete is flowing, the tremie shall be raised in a manner reviewed without objection by the Project Manager; the lower end of the tremie shall be kept immersed in the concrete to a depth of at least 1 m. Water, mud and other deleterious material shall be prevented from entering the tremie after concreting has started.

(c) If the tremie becomes blocked or is removed from the concrete, concreting shall be stopped immediately. Concreting shall not recommence for at least 24 hours; contaminated concrete shall be removed before concreting commences.

(d) Concrete placed by tremie shall be placed above the specified level by an amount to allow for the removal of concrete, including laitance and excess cement slurry. Contaminated concrete shall be removed.

20.7.13 Compacting Concrete

(a) Concrete shall be compacted to form a dense homogeneous mass.

(b) Concrete shall be compacted by means of internal vibrators of suitable diameter. A sufficient number of vibrators shall be maintained in serviceable condition on Site to ensure that spare equipment is available in the event of breakdown.

(c) Vibrators shall be used in such a manner that vibration is applied continuously and systematically during placing of the concrete until the expulsion of air has practically ceased. Vibrators shall not be used in a manner which will result in segregation. Internal vibrators shall be inserted to the full depth of the concrete placed and shall be withdrawn slowly.

(d) Vibration shall not be applied by way of the reinforcement, and contact between internal vibrators and formwork, reinforcement or built-in components shall be avoided as far as possible. Concrete shall be vibrated in such a manner that the formwork, reinforcement or built-in components shall not be displaced.

(e) Concrete which has been in position for more than 30 minutes shall not be vibrated.

(f) No-fines concrete shall be compacted using a minimum amount of punning.

(g) Vibrating equipment shall comply with BS 2769:Part 2 and the following:

(i) internal vibrators operating at a minimum of 10,000 cycles per minute;

(ii) external vibrators operating at a minimum of 3,000 cycles per minute;
(iii) vibrating tables operating at a minimum of 5,000 oscillations per minute may be used for precast elements subject to review by the Project Manager; and

(iv) external clamp-on type, vibrators shall not be used.

20.7.14 Construction Joints

(a) Construction joints in concrete shall be formed only at the specified positions and by the specified method. The position and details of construction joints which are not stated in the Contract shall be arranged in such a manner that the possibility of the occurrence of shrinkage cracks is minimised.

(b) Construction joints shall be normal to the axis or plane of the element being constructed.

(c) Waterstops shall be provided at construction joints in water retaining structures, tunnels and at any other locations as shown on the Employer's Drawings.

(d) Laitance and loose material shall be removed from the surface of construction joints and the aggregate shall be exposed by a method reviewed without objection by the Project Manager. The work shall be carried out as soon as practicable after the concrete has hardened sufficiently for the cement matrix to be removed without disturbing the coarse aggregate. The surface of the construction joint shall be cleaned after the matrix has been removed.

(e) The surface of the construction joint shall be clean and dry before fresh concrete is placed against it.

20.7.15 Curing Concrete

(a) Concrete shall be protected against harmful effects, including those due to weather, running water and drying out by one of the following methods:

(i) Method 1: A liquid curing compound shall be applied to the concrete surface by a low-pressure spray at the rate recommended by the manufacturer until a continuous visible covering is achieved;

(ii) Method 2: The concrete surface shall be covered with hessian, sacking, canvas or with a layer of fine aggregate at least 25 mm thick; the hessian, sacking, canvas or fine aggregate shall be kept constantly wet;

(iii) Method 3: The concrete surface shall be covered with polyethylene sheeting; concrete surfaces which have become dry shall be thoroughly wetted before the sheeting is placed; or

(iv) Method 4: Unformed concrete surfaces shall be covered with polyethylene sheeting until the concrete has hardened sufficiently for water curing to be carried out. Water curing shall be carried out by spraying the concrete surface continuously with cool water or by ponding immediately after the sheeting is removed. If in the opinion of the Project Manager water curing is impracticable, Method 2 shall be used instead of water curing.
(b) Method 1 shall not be used on concrete surfaces against which concrete will be placed or which will have a Class T1 finish or which will be painted or tiled.

(c) Methods 1, 2, 3 or 4 shall be used on unformed concrete surfaces immediately after the concrete has been compacted and finished. Methods 1, 2 or 3 shall be used on formed concrete surfaces immediately after the formwork has been removed.

(d) Polyethylene sheeting shall be impermeable and shall have a nominal thickness of 0.125 mm.

(e) Hessian, sacking, canvas and polyethylene sheeting shall be lapped and securely held in position in such a manner that the concrete surface will not be damaged.

(f) Cold water shall not be applied to concrete surfaces or formwork.

(g) The different methods of protection shall be maintained for the minimum periods stated in Table 20.8 after the concrete has been placed. The minimum periods may, subject to review without objection by the Project Manager, be reduced by the number of days during which formwork is left in position.

(h) When the ambient temperature exceeds 32°C full hot weather curing techniques as described in ACI document ACI 305R-89, shall be implemented. Absorptive wood forms remaining in place shall not be considered a satisfactory means of curing in hot dry weather. Such forms shall be covered and kept moist.

### Table 20.8: Minimum Periods of Protection for Concrete

<table>
<thead>
<tr>
<th>Type of Structure</th>
<th>Method of protection</th>
<th>Minimum period of protection (days)</th>
<th>Concrete not containing PFA or PPFAC</th>
<th>Concrete containing PFA or PPFAC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water retaining structures, tunnels, and water tight structures</td>
<td>1</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2, 3 or 4</td>
<td>7</td>
<td>9</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>1</td>
<td>7</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2, 3 or 4</td>
<td>4</td>
<td>5</td>
<td></td>
</tr>
</tbody>
</table>

20.7.16 Manufacture of Precast Concrete Units

(a) For all prestressed pretensioned members the length, cross section dimensions and straightness of precast concrete shall be measured at 28 ± 2 days after casting;

(b) Unless otherwise stated in the Contract the allowable dimensional variations for precast concrete units shall not exceed those given in Table 20.9.
Table 20.9 Allowable Dimensional Variations

<table>
<thead>
<tr>
<th>Length</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 3 m</td>
<td>± 6 mm</td>
</tr>
<tr>
<td>3 to 4.5 m</td>
<td>± 9 mm</td>
</tr>
<tr>
<td>4.5 to 6 m</td>
<td>± 12 mm</td>
</tr>
<tr>
<td>Additional for every</td>
<td>± 6 mm</td>
</tr>
<tr>
<td>subsequent 6 m</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cross Section (each direction)</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 500 mm</td>
<td>± 6 mm</td>
</tr>
<tr>
<td>500 to 750 mm</td>
<td>± 9 mm</td>
</tr>
<tr>
<td>Additional for every</td>
<td></td>
</tr>
<tr>
<td>subsequent 250 m</td>
<td>± 3 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Straightness or bow (deviation from intended line)</th>
<th>Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 3 m</td>
<td>6 mm</td>
</tr>
<tr>
<td>3 to 6 m</td>
<td>9 mm</td>
</tr>
<tr>
<td>6 to 12 m</td>
<td>12 mm</td>
</tr>
<tr>
<td>Additional for every</td>
<td></td>
</tr>
<tr>
<td>subsequent 6 m</td>
<td>6 mm</td>
</tr>
</tbody>
</table>

Where the Project Manager requires tests to be carried out on members manufactured off-Site, no members to which the tests relate shall be dispatched to Site until the tests have been completed and the results reviewed without objection by the Project Manager.

All members shall be indelibly marked to show the description of the member as shown on the Employer's Drawings, the production line on which they were manufactured, the date on which the concrete was cast and, if they are of symmetrical section, the face that will be uppermost when the member is in its correct position in the Permanent Works. The markings shall be so located that they are not exposed to view when the member is in its permanent position.

Unless otherwise specified the vibrated top surface of precast concrete members which will subsequently receive in-situ concrete shall be further prepared by the following methods:

(i) when the concrete is self-supporting but still sufficiently green the concrete surface shall be sprayed with a fine spray of water or brushed with a stiff brush just sufficiently to remove the outer mortar skin and expose the larger aggregate without disturbing it; or

(ii) alternatively where this preparation proves impracticable the hardened surface skin and laitance shall be removed by sand blasting or a needle gun.

Hardened surfaces shall not be hacked.

Retarding agents shall not be used.

The joint surface shall be clean and damp but free of standing water immediately before any fresh concrete is placed against it.
20.7.17 Installation of Precast Concrete Units

(a) Contact surfaces between in-situ concrete and precast concrete units shall be prepared as stated in the Contract. Dimensional tolerances shall be checked before the precast concrete units are lifted into position.

(b) Temporary supports and connections shall be provided as soon as practicable during installation of precast concrete units.

(c) Final structural connections shall be completed as soon as practicable after the precast concrete units have been installed.

(d) Levelling devices which have no load bearing function in the finished structure shall be slackened, released or removed after the precast concrete units have been installed.

20.7.18 Loading of Concrete

(a) Loads which will induce a compressive stress in the concrete exceeding one-third of the compressive strength of the concrete at the time of loading or exceeding one-third of the grade strength, whichever is less, shall not be applied to concrete; allowance shall be made for the weight of the concrete in determining the loading. The strength of the concrete and the stresses produced by the loads shall be assessed by a method reviewed without objection by the Project Manager.

(b) Loads from materials not forming part of the Permanent Works or from Contractor's Equipment or other vehicles, shall not be applied to no-fines concrete.

20.7.19 Storage of Materials for Joints

(a) Bitumen emulsion, joint sealant and primer for joint sealant shall be stored in sealed containers marked to identify the contents and protected from exposure to conditions which may affect the material. The materials shall be stored in accordance with the manufacturers' recommendations and shall not be used after the recommended shelf life has been exceeded.

(b) Joint filler, bond breaker tape and waterstops shall be stored in accordance with the manufacturers' recommendations in a dry weatherproof store with a raised floor. Absorbent joint filler shall be stored in sealed plastic bags and shall not be exposed to moisture or air.

(c) Bearing strip for sliding joints supplied in rolls of 5 m length or less shall be unrolled immediately after delivery and shall be stored flat at full length on an even surface. Bearing strip supplied in rolls of more than 5 m length may be left in the original packing. Bearing strip shall be stored in accordance with the manufacturer's recommendations and shall be protected from mechanical damage and creasing; the two layers of strip shall be kept free from deleterious material.

20.7.20 Forming Joints

(a) Materials for joints shall be mixed and used in accordance with the manufacturers' recommendations.

(b) Joint filler shall be cut to size before fixing and shall be securely fixed in position to the existing concrete surface before concreting. There shall be no gaps between the joint filler and formation.
(c) Waterstops shall be securely fixed in position to formwork in such a manner that compaction of the concrete will not be affected. In-situ joints in waterstops shall be made using methods and equipment recommended by the manufacturer. Exposed waterstops shall be protected from exposure to conditions which may affect the waterstop and shall be kept free from rust, hydrocarbons and other deleterious material.

(d) Joints shall be formed in straight lines perpendicular to the surface of the concrete unless otherwise stated in Contract.

(e) Saw-cut joints shall be formed where shown on the Employer's Drawings, in slab-on-ground areas. Joints shall be formed by use of a rotary-concrete saw to the depths shown on the Employer's Drawings.

### 20.7.21 Forming Grooves

(a) Grooves for joint sealant shall be straight and shall be perpendicular to the surface of the concrete. The bottom of the groove shall be flat and shall be parallel to the surface of the concrete.

(b) Grooves shall be formed by using timber or other formers reviewed without objection by the Project Manager and shall not be formed by cutting back or raking out the joint filler. The grooves shall be located over the joint filler such that the upper surface of the joint filler is entirely contained in the groove.

### 20.7.22 Protection of Grooves

Before permanent sealing, grooves for joint sealant shall be protected from contamination by a temporary sealing strip or cover.

### 20.7.23 Sealing Joints

(a) The permanent sealing of joints shall be carried out at least 7 days after concreting.

(b) Immediately before permanent sealing, timber formers, temporary seals, dirt and loose material shall be removed from the groove and the sides of the groove shall be cleaned and roughened by water jetting or sand blasting.

(c) Caulking material shall be firmly packed in the bottom of the groove if the joint sealant is not required to extend to the bottom of the groove.

(d) Bond breaker tape shall be fixed continuously and evenly along the bottom of the groove for the full width and length of the groove.

(e) Concrete surfaces within 75 mm of the edges of the joint shall be masked with tape before the primer is applied and until the sealing of the joint is complete.

(f) Primer for the joint sealant shall be applied to the sides of the groove in accordance with the manufacturer's recommendations.
(g) Joint sealant shall be applied between the minimum and maximum drying times of the primer recommended by the manufacturer. The components of the sealant shall be thoroughly mixed in accordance with the manufacturer's recommendations using a power operated paddle mixer for sufficient time to produce a homogeneous mass without entrapped air. The sealant shall be dispensed into the groove as soon as practicable after mixing and within the time recommended by the manufacturer.

(h) The groove shall be clean and dry at the time of applying the primer and joint sealant.

(i) Excess joint sealant shall be removed by using a purpose made finishing tool such that the finished surface of the sealant is between 4 mm and 6 mm below the face of the concrete.

20.7.24 Strip and Pad Bearing Installation

(a) The concrete surface shall be prepared with a mortar pad as specified on the Employer's Drawings. The mortar pad should be a minimum of 10 mm thick. The top surface of the mortar pad must not deviate by more than 3 mm in 1 m for strip bearings and no more than 2 mm across the mortar seating for pad bearings. The thickness of the mortar pad shall be such as to allow the bearing to be seated within the nominal 50 mm distance between concrete bearing faces, without intrusion into the upper concrete element concrete cover. The maximum thickness of mortar pad shall be 30 mm.

(b) The bearing shall be placed in position on the mortar pad and fixed in position with epoxy adhesive of a type recommended by the bearing manufacturer and reviewed without objection by the Project Manager.

(c) The areas around the bearing must be blocked out with a void former to ensure that concrete, when poured in the upper element cannot contact the lower concrete element.

20.7.25 Tolerances: Joints

(a) The line of straight joints shall be within 10 mm of the true line.

(b) The line of curved joints shall be within 10 mm of the true curved line.

(c) Joints shall be continuous across intersections of joints to within 5 mm of the joint opposite.

(d) The depth of grooves for joint sealant shall be within 3 mm of the specified depth.
20.8 INSPECTION, TESTING & COMMISSIONING

20.8.1 Batch: Cement, PFA, Aggregate, Admixture, Curing Compound

A batch of cement, PFA, aggregate, admixture or curing compound is any quantity of cement, PFA, aggregate, admixture or curing compound of the same type, manufactured or produced at the same time in the same place, covered by the same certificates and delivered to Site, or stored at the ready-mixed concrete plant, at any one time.

20.8.2 Samples: Cement, PFA, Aggregate, Admixture, Curing Compound, Water

(a) One sample of each type of cement, PFA, aggregate, admixture, curing compound and water shall be provided at the same time as particulars of the material are submitted to the Project Manager for review.

(b) The size of each sample and the method of sampling shall be as stated in Table 20.10.

20.8.3 Testing: Cement, PFA, Aggregate, Admixture, Curing Compound, Water

(a) Each sample of cement, PFA, aggregate, admixture, water and curing compound shall be tested to determine the properties stated in Table 20.11.

(b) The method of testing shall be as stated in Table 20.11.

(c) The maximum total sulphate and chloride content of concrete shall be determined on the basis of the results of tests for chloride content of each constituent.

20.8.4 Control of Alkali-aggregate Reaction in Concrete

(a) Measures to control the occurrence of alkali-aggregate reaction (AAR) in concrete shall be in accordance with Practice Note for Authorized Persons and Registered Structural Engineers No. 180 and submitted for review by the Project Manager. Such control shall be achieved by limiting the reactive alkali content of the concrete as described in Clauses (b) - (d) unless in the opinion of the Project Manager the concrete element will not be subjected to moisture ingress throughout its design life.

(b) The reactive alkali content of concrete expressed as the equivalent sodium oxide per cubic metre of concrete shall not exceed 3.0 kg.

(c) The equivalent sodium oxide (Na₂O) content of concrete shall be calculated from the following expression:

\[
\text{Equivalent Na}_2\text{O} = \frac{A}{B} \div \frac{C}{1}
\]

(i) where A is the sum of the acid-soluble alkalis (expressed as equivalent Na₂O) of cement, admixtures and water; B is equal to 1/6 of the total alkalis of PFA (expressed as equivalent Na₂O); and C is equal to 0.76 times the chloride ion (Cl⁻) of the aggregate;

(ii) the acid-soluble alkali content of the cement shall be determined in accordance with BS 4550:Part 2:1970 (excluding amendment AMD 7285, July 1992) and shall be taken as the average of the latest 25 daily determinations of equivalent sodium oxide plus twice the standard deviation of the results;

(iii) the acid-soluble alkali content of admixtures shall be determined in accordance with BS 1881:Part 124:1988;
(iv) the acid-soluble alkali content of water shall be determined in accordance with APHA (17ed. 1989) Sections 3500-K and 3500Na;

(v) the total alkali content of the pulverised fuel-ash shall be determined in accordance with BS 4550:Part 2:1970 (excluding amendment AMD 7285, July 1992) and shall be taken as the average of the latest 25 daily determinations of equivalent sodium oxide plus twice the standard deviation of the results; and

(vi) the equivalent sodium oxide content of the coarse and fine aggregates shall be calculated from the quantity of chloride ion present which shall be measured in accordance with BS 812:Part 4:1976.

(d) The following particulars of the proposed concrete mix shall be submitted for review by the Project Manager:

(i) HOKLAS endorsed test certificates not older than 6 months giving the results of tests required in Clauses 20.8.4 (c) (ii)-(vi), with new HOKLAS test certificates submitted at quarterly intervals together with any necessary further calculations to demonstrate that the mix continues to comply with the limit on reactive alkali; and

(ii) calculations of the reactive alkali of the proposed mix.

Table 20.10: Size of Samples and Method of Sampling Cement, PFA, Aggregate, Admixture, Curing Compound and Water

<table>
<thead>
<tr>
<th>Material</th>
<th>Size of sample</th>
<th>Method of sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>20 kg</td>
<td>BS 4550:Part 1</td>
</tr>
<tr>
<td>PFA</td>
<td>20 kg</td>
<td>BS 4550:Part 1</td>
</tr>
<tr>
<td>PPFAC</td>
<td>20 kg</td>
<td>BS 4550</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>25 kg</td>
<td>BS 812:Part 102</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>10 kg</td>
<td>BS 812:Part 102</td>
</tr>
<tr>
<td>Water</td>
<td>10 L</td>
<td>BS 3148</td>
</tr>
<tr>
<td>Admixture (powdered)</td>
<td>1 kg</td>
<td>BS 5075:Part 1</td>
</tr>
<tr>
<td>Admixture (liquid)</td>
<td>1 L</td>
<td>BS 5075:Part 1</td>
</tr>
<tr>
<td>Curing compound</td>
<td>5 L</td>
<td>BS 5075:Part 1</td>
</tr>
</tbody>
</table>
### Table 20.11: Methods of Testing Cement, PFA, Aggregate, Admixture, Curing Compound and Water

<table>
<thead>
<tr>
<th>Material</th>
<th>Property</th>
<th>Method of testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>OPC, RHPC, SRPC, PPFAC</td>
<td>Chemical composition</td>
<td>BS 4550:Part 2</td>
</tr>
<tr>
<td></td>
<td>Fineness</td>
<td>BS 4550:Part 3</td>
</tr>
<tr>
<td></td>
<td>Compressive strength at 3, 7 and 28 days</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Initial and final setting times</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Soundness</td>
<td></td>
</tr>
<tr>
<td>PPFAC</td>
<td>Proportion by mass of PFA</td>
<td>BS 6588</td>
</tr>
<tr>
<td>PFA</td>
<td>Chemical composition</td>
<td>BS 3892:Part 1</td>
</tr>
<tr>
<td></td>
<td>Fineness</td>
<td>BS 3892:Part 1</td>
</tr>
<tr>
<td></td>
<td>Moisture content</td>
<td></td>
</tr>
<tr>
<td>Coarse aggregate, fine aggregate</td>
<td>Grading</td>
<td>BS 812:Part 103</td>
</tr>
<tr>
<td></td>
<td>Silt content</td>
<td>BS 812:Part 1</td>
</tr>
<tr>
<td></td>
<td>Chloride content</td>
<td>BS 812:Part 1</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>Flakiness index</td>
<td>BS 812:Part 105.1</td>
</tr>
<tr>
<td></td>
<td>Ten percent fines</td>
<td>PS 812:Part 111</td>
</tr>
<tr>
<td></td>
<td>Water absorption</td>
<td>BS 812:Part 2</td>
</tr>
<tr>
<td>Admixture</td>
<td>Chloride content</td>
<td>BS 5075 : Part 1</td>
</tr>
<tr>
<td>Curing compound</td>
<td>Efficiency index</td>
<td>Appendix 20A.1</td>
</tr>
<tr>
<td>Water</td>
<td>Initial setting times of cement</td>
<td>BS 3148</td>
</tr>
<tr>
<td></td>
<td>compressive strength of test cubes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Organic content</td>
<td>By inspection</td>
</tr>
<tr>
<td></td>
<td>Inorganic impurities content</td>
<td>APHA 209A</td>
</tr>
<tr>
<td></td>
<td>Chloride content</td>
<td>ASTM D512-81, Method B</td>
</tr>
<tr>
<td></td>
<td>Sulphide content</td>
<td>ASTM D516-80, Method A</td>
</tr>
<tr>
<td></td>
<td>Alkaline carbonate and bicarbonate content</td>
<td>AOAC 1984, Text 33.076</td>
</tr>
<tr>
<td></td>
<td>pH value</td>
<td>ASTM D1293-78</td>
</tr>
</tbody>
</table>

#### 20.8.5 Batch: Concrete

A batch of concrete is any quantity of concrete produced in one cycle of operations of a batch mixer, or conveyed ready-mixed in a delivery vehicle, or discharged during one minute from a continuous mixer.

#### 20.8.6 Reduction of Resting Frequency

The number of tests for workability or compressive strength of standard mix concrete may be reduced if after review without objection by the Project Manager it is confirmed that the standard of quality control is satisfactory.
20.8.7 Samples: Workability of Concrete

(a) One sample of concrete shall be provided from each batch of concrete to determine the workability of the concrete.

(b) The size of each sample and the method of sampling shall be in accordance with CS1 except that if a superplasticising admixture is included in the concrete mix to produce flowing concrete, the sample shall be taken before the superplasticiser is added.

20.8.8 Testing: Workability of Concrete

(a) Each sample of concrete taken as stated in Section 20.8.7 shall be divided into two specimens; each specimen shall be tested to determine the workability of the concrete. The method of testing shall be the slump test in accordance with CS1.

(b) The average of the two slump values shall be calculated and referred to as the average slump value.

20.8.9 Compliance Criteria: Workability of Concrete

(a) The average slump value of the two specimens taken from one sample of standard mix concrete shall be within the appropriate range stated in Table 20.1.

(b) The average slump value of the two specimens taken from one sample of designed mix concrete shall be within 25 mm or 33% of the "Acceptable Slump Value", whichever is the greater.

20.8.10 Non-compliance: Workability of Concrete

A batch of concrete shall be considered as not complying with the specified requirements for workability if the result of any test for workability, carried out on a sample taken from the batch, does not comply with the specified requirements for workability.

20.8.11 Samples: Compressive Strength of Concrete

(a) For each concrete mix, one sample of concrete shall be provided from each amount of concrete as stated in Table 20.12 or from the amount of concrete produced each day, whichever is less. The sample shall be selected at random as follows:

(i) at the point of discharge from the mixer; or

(ii) in the case of ready-mixed concrete, at the point of discharge from the delivery vehicle; or

(iii) elsewhere as directed by the Project Manager; and

(iv) in no case to be from the first 0.3 m³ of concrete discharged from the truck.

(b) If the Contractor requests, or if the Project Manager directs, that the concrete be tested for compressive strength at ages other than 28 days, additional samples shall be provided. The number of additional samples shall be as stated in Section 20.8.11(a).

(c) The size of each sample and the method of sampling shall be in accordance with CS1. If a superplasticising admixture is included in the concrete mix, the samples shall be taken after the superplasticiser is added and after the concrete is remixed.
### Table 20.12: Rate Sampling of Concrete

<table>
<thead>
<tr>
<th>Type of structure</th>
<th>Amount of concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masts</td>
<td>10 m³ or 10 batches, whichever is less</td>
</tr>
<tr>
<td>Cantilevers 3 m or more in length</td>
<td></td>
</tr>
<tr>
<td>Columns</td>
<td></td>
</tr>
<tr>
<td>Shear walls</td>
<td></td>
</tr>
<tr>
<td>Prestressed elements</td>
<td></td>
</tr>
<tr>
<td>Other critical elements</td>
<td></td>
</tr>
<tr>
<td>Solid rafts</td>
<td>100 m³ or 100 batches, whichever is less</td>
</tr>
<tr>
<td>Pile caps</td>
<td></td>
</tr>
<tr>
<td>Mass concrete</td>
<td></td>
</tr>
<tr>
<td>Retaining walls</td>
<td></td>
</tr>
<tr>
<td>Other types</td>
<td>25 m³ or 25 batches, whichever is less</td>
</tr>
</tbody>
</table>

#### 20.8.12 Testing: Compressive Strength of Concrete

(a) Two 150 mm test cubes shall be made from each sample of concrete taken as stated in Section 20.8.11. Each pair of test cubes shall be tested to determine the compressive strength at 28 days.

(b) The method of making test cubes shall be in accordance with CS1.

(c) The method of storing test cubes shall be in accordance with CS1. Test cubes which are cured on Site shall be delivered to the HOKLAS accredited testing laboratory at least 48 hours before the tests are due to be carried out.

(d) The method of testing shall be in accordance with CS1.

(e) For the purpose of assessing compliance of designed mix concrete as stated in Sections 20.8.14 and 20.8.15, the average of the two compressive strengths of the pair of test cubes shall be calculated and referred to as the test result.

#### 20.8.13 Non-compliance: Compressive Strength of Standard Mix Concrete

If the result of any test for compressive strength at 28 days of standard mix concrete is less than the grade strength, the Project Manager may direct that tests as stated in Sections 20.8.16 to 20.8.19 be carried out on concrete cores or on samples taken from the hardened concrete.

#### 20.8.14 Compliance Criteria: Compressive Strength of Designed Mix Concrete

The results of tests for compressive strength at 28 days of designed mix concrete shall comply with Clause 59 of the Building (Construction) Regulations of Hong Kong.

#### 20.8.15 Non-compliance: Compressive Strength of Designed Mix Concrete

If designed mix concrete is considered as not complying with the specified requirements for compressive strength as stipulated in Clause 59 of the Building (Construction) Regulations of Hong Kong, the Project Manager may direct that tests as stated in Sections 20.8.16 to 20.8.19 are carried out on concrete cores or on samples taken from the hardened concrete.
20.8.16  Samples: Hardened Concrete and Concrete Cores

(a)  The number of samples, including cores, of hardened concrete to be provided for testing shall be as stated in the Contract or, if testing is to be carried out as a result of the concrete not complying with the Specification, shall be as directed by the Project Manager and to the satisfaction of the Buildings Department. In the event testing is directed as a result of concrete not complying with the Specification, all the concrete being investigated shall be divided as directed by the Project Manager into separate test locations. The number of samples taken from each location shall be as directed by the Project Manager and the quality of concrete at each location shall be assessed separately. The positions from which the samples are taken shall be as directed by the Project Manager.

(b)  The size of samples and the method of sampling shall be in accordance with CS1.

20.8.17  Testing: Concrete Cores

(a)  Each concrete core shall be inspected for evidence of segregation of the constituents and for the presence of voids. Specimens selected from each core shall be tested to determine the compressive strength.

(b)  The method of preparing and inspecting concrete cores and of testing the cores to determine the compressive strength shall be in accordance with CS1. Concrete cores shall not be tested for compressive strength until the concrete has reached an age of 28 days.

20.8.18  Compliance Criteria: Concrete Cores

(a)  Concrete cores shall not show evidence of segregation. The extent of voids in the core shall not be more than 'few' in accordance with Table 4 of CS1 and there shall be no honeycombing.

(b)  The results of tests for compressive strength of concrete cores shall be interpreted in accordance with BS 6089. Adjustments to the measured strength in respect of the age of the core when tested shall not be made. The estimated equivalent cube strength of each core specimen shall be calculated in accordance with CS1. Subject to the approval of the Buildings Department, for any set of cores representing a test location, the average estimated equivalent cube strength shall be at least 85% of the specified grade strength, and each individual estimated equivalent cube strength shall be at least 75% of the specified grade strength.

20.8.19  Analysis of Hardened Concrete

(a)  Each sample of hardened concrete shall be tested to determine the properties or the composition of the concrete as stated in the Contract or, if testing is to be carried out as a result of the concrete not complying with the specified requirements, shall be tested as directed by the Project Manager.

(b)  Tests on hardened concrete shall be carried out within 14 days of the Project Manager's request for the test.

(c)  The method of testing shall be in accordance with CS1.

(d)  When directed by the Project Manager, in-situ rebound hammer tests to determine the strength of hardened concrete shall be undertaken in accordance with BS EN 12504-2:2001.
20.8.20 **Batch: Precast Units**

A batch of precast units is any quantity of precast units, including prestressed units, of the same type and size, of the same concrete mix, manufactured in the same place, covered by the same certificates and delivered to Site at any one time.

20.8.21 **Samples: Precast Units**

The number of precast units to be provided for testing from each batch shall be as stated in the Contract.

20.8.22 **Testing: Precast Units**

(a) Load tests shall be carried out to determine the deflection and recovery of each precast unit, including prestressed units, provided for testing and to determine the resistance to cracking of each prestressed unit provided for testing.

(b) Load tests shall be carried out in accordance with a procedure submitted to and reviewed without objection by the Project Manager. The age at which the units are to be tested, the test load, the points at which the loads are to be applied and the points at which the unit is to be supported shall be as stated in the Contract or as proposed by the Contractor and reviewed without objection by the Project Manager.

(c) The method of testing shall be as stated in Appendix A20.2.

(d) Post-tensioned units shall not be tested until at least 7 days after the ducts have been grouted.

20.8.23 **Compliance Criteria: Precast Units**

The results of load tests on precast units shall comply with the requirements stated in the Contract.

20.8.24 **Batch: Joint Filler, Joint Sealant, Waterstops**

A batch of joint filler, joint sealant or waterstop is any quantity of joint filler, joint sealant or waterstop of the same type, manufactured by the same manufacturer, covered by the same certificates and delivered to Site at any one time.

20.8.25 **Samples: joint filler, joint sealant, waterstops**

(a) One sample of each type of joint filler, joint sealant or waterstop shall be provided at the same time as particulars of the material are submitted to the Project Manager for review. One sample of each type of material shall be provided from each batch of the material delivered to Site. One sample of mixed joint sealant shall be provided on each day that joints are sealed.

(b) The size of each sample of joint filler shall be sufficient to permit all tests stated in Appendix A20.3 to be carried out.
(c) Samples of unmixed joint sealant and primers for joint sealant shall be taken from sealed containers delivered to Site. Samples of mixed joint sealant shall be taken immediately before the sealant is applied to the joint. The method of sampling shall be as stated in BS 2499, Appendix A. The size of each sample shall be as follows:

(i) unmixed joint sealant : 1 kg;

(ii) mixed joint sealant : 1.5 kg; and

(iii) primer for joint sealant : 1 L.

(d) The size of each sample of waterstop shall be 1 m.

20.8.26 Testing: Joint Filler, Joint Sealant, Waterstops

(a) Samples of joint filler shall be tested to determine the disintegration and shrinkage, the recovery value and reduction in mass and the extrusion. The method of testing shall be in accordance with Appendix A20.3.

(b) Samples of joint sealant shall be tested to determine the properties stated in Table 20.13. The method of testing shall be as stated in Table 20.13.

(c) Samples of waterstop shall be tested to determine the properties stated in Table 20.14. The method of testing shall be as stated in Table 20.14.

Table 20.13: Testing Joint Sealant

<table>
<thead>
<tr>
<th>Type of joint sealant</th>
<th>Properties to be tested</th>
<th>Method of testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polysulphide-based sealant</td>
<td>Rheological properties</td>
<td>BS 4254</td>
</tr>
<tr>
<td>Polyurethane-based sealant</td>
<td>Plastic deformation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adhesion and tensile modulus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Application life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adhesion in peel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loss of mass after heat ageing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Staining</td>
<td></td>
</tr>
<tr>
<td>Hot-applied bitumen rubber</td>
<td>Extension</td>
<td>BS 2499</td>
</tr>
<tr>
<td>sealant</td>
<td>Flow</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Penetration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degradation</td>
<td></td>
</tr>
</tbody>
</table>
Table 20.14 : Testing Waterstops

<table>
<thead>
<tr>
<th>Property</th>
<th>Method of testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rubber waterstops</td>
</tr>
<tr>
<td>Density</td>
<td>BS 903:Part A1</td>
</tr>
<tr>
<td>Hardness</td>
<td>BS 903:Part A26</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>BS 903:Part A2 and BS 903:Part A5</td>
</tr>
<tr>
<td>Elongation at break point</td>
<td>BS 903:Part A2 and BS 903:Part A5</td>
</tr>
<tr>
<td>Water absorption</td>
<td>BS 903:Part A18</td>
</tr>
<tr>
<td>Softness number</td>
<td>-</td>
</tr>
</tbody>
</table>

20.8.27 Compliance Criteria: Joint Filler

(a) The results of tests on joint filler shall comply with the following requirements:

(i) none of the three specimens in the weathering test shall show any sign of disintegration or shrinkage;

(ii) each of the four specimens in the compression and recovery test shall have a recovery value of at least 70%, and the reduction in mass of each of the two new specimens shall not exceed 1%; and

(iii) the extrusion of the free edge of the specimen shall not exceed 6 mm as determined by the extrusion test.
APPENDIX A20.1

DETERMINATION OF THE EFFICIENCY INDEX OF CURING COMPOUNDS

A20.1.1 Scope

This method covers the determination of the efficiency index of membrane forming curing compounds for concrete.

A20.1.2 Materials

(a) The following materials are required:

(i) Ordinary Portland cement complying with BS 12, specially selected for testing admixtures and identified as 'CAA/BS 5075:Part 1 Reference Portland Cement'; the cement shall be stored in an airtight container;

(ii) oven-dry natural sand with a rounded particle shape complying with BS 882 and with the grading stated in Table A20.1.1; and

(iii) petroleum jelly, mineral oil or a proprietary release agent.

Table A20.1.1 : Grading of Sand

<table>
<thead>
<tr>
<th>BS test sieve</th>
<th>Percentage by mass passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.18 mm</td>
<td>100</td>
</tr>
<tr>
<td>600 μm</td>
<td>90 - 100</td>
</tr>
<tr>
<td>300 μm</td>
<td>12 - 40</td>
</tr>
<tr>
<td>150 μm</td>
<td>0 - 6</td>
</tr>
</tbody>
</table>

A20.1.3 Apparatus

(a) The following apparatus is required:

(i) moulds constructed of corrosion resistant metal. The moulds shall be watertight, tapered and constructed so as to prevent distortion and shall have the following dimensions:

- internal size (top): 150 mm (0 mm to +5 mm) x 300 mm (0 mm to +5 mm);
- internal size (bottom): 145 mm (0 mm to +5 mm) x 295 mm (0 mm to +5 mm);
- internal depth: 50 mm ± 2 mm;
- side and end slope: 5% ± 1%; and
- top flange width: at least 12 mm;

(ii) a balance readable and accurate to 0.1 g;

(iii) a cabinet complying with BS 2648 capable of storing specimens at a temperature of 38°C ± 1°C and at a relative humidity of 35% ± 5%. The cabinet shall have three perforated or mesh shelves each capable of supporting two specimens during the test so as to ensure a clear space of at least 40 mm on
all sides of individual specimens. The cabinet shall be equipped to circulate air
over the specimens at an approximate rate of 0.5 m/s;

(iv) spray equipment, such as the Wagner model W320 electric spray gun, designed
to permit the curing compound to be aspirated and applied evenly to the
specimen;

(v) an electrically driven mixer complying with Clause 8.3 of BS 4551 and having
a nominal capacity of 12 kg;

(vi) a vibrating table or a vibrating hammer with a 40 mm square foot or a
compacting bar made of non-absorbent material, approximately 200 mm long
and with a 40 mm square foot;

(vii) a metal screed, 148 mm long, of L-shaped section 50 mm x 25 mm with the
shorter side having a sharpened leading edge. The screed shall be supported
across the top of the mould by a 200 mm long rigid member which can slide on
the flanges of the mould while holding the screed horizontal. The height of the
screed shall be adjustable to give a uniformly flat surface finish to the mortar
7 mm ± 1 mm below the top of the mould;

(viii) a metal tray with sides at least 3 mm high and an area equal to the surface area
of the specimen;

(ix) a hydrometer complying with BS 718;

(x) a float, 250 mm x 140 mm ± 5 mm; and

(xi) a medium soft 50 mm paint brush.

A20.1.4 Procedure: Preparation of Specimens

(a) The procedure for preparation of the specimens shall be as follows:

(i) three pairs of specimens shall be prepared, each pair comprising one test
specimen and one control specimen;

(ii) mixing shall be carried out in a room having a temperature of 27°C ± 3°C. The
materials shall be brought to room temperature before mixing. A mortar mix
shall be prepared comprising one part by mass of cement, three parts by mass
of sand and 0.44 parts by mass of water;

(iii) the sand and cement shall be placed in the mixer and mixed for 1 minute. The
water shall be added and mixing continued for a further 4 minutes;

(iv) the two moulds shall be cleaned, lightly coated with the petroleum jelly,
mineral oil or release agent and weighed to the nearest 0.1 g (m1);

(v) the specimens shall be prepared 20 minutes after completion of mixing and
shall be cast in pairs;

(vi) a layer of mortar approximately 25 mm deep shall be placed in each mould
and tamped 50 times with the compacting bar. A second layer of mortar,
sufficient to overfill the moulds slightly, shall be placed in each mould and
tamped 50 times with the compacting bar. Indentations formed by tamping
shall be filled and the surface shall be levelled by vigorous compaction by
manual methods. Alternatively, each layer shall be compacted by using the vibrating table or vibrating hammer and levelled using the float;

(vii) a uniform surface, free from undulations and surface defects, shall be produced using the minimum number of passes of the metal screed working along the length of the mould in both directions. The finished surface shall be 7 mm ± 1 mm below the top of the mould;

(viii) the surface shall be brushed lightly with the paint brush to give an even texture; and

(ix) The moulds and specimens shall each be weighed to the nearest 0.1 g (m$_2$) immediately before the curing compound is applied.

A20.1.5 Procedure: Determination of Efficiency Index

(a) The procedure for determination of the efficiency index shall be as follows:

(i) a sample of the curing compound shall be taken by the method for sampling admixtures in accordance with BS 5075:Part 1, Appendix A;

(ii) the sample shall be agitated thoroughly and the relative density determined at room temperature with the hydrometer. The mass required to give the coverage rate stated in Section A20.1.5(c) shall be calculated from the relative density. The mass of the curing compound applied shall be within ± 0.5 g of that required to give the specified coverage rate;

(iii) the curing compound shall be applied at the coverage rate recommended by the manufacturer, or at a rate of 0.2 L/m$^2$ ± 0.01 L/m$^2$ if no rate is recommended;

(iv) the curing compound shall be applied to the test specimen one hour after the specimen has been prepared, using the spray equipment or in accordance with the manufacturer's recommendations. The curing compound shall be shaken well before and during application. The spray gun shall be held so that the nozzle is as near vertical as possible and at a height which will result in uniform application and minimum overspray. The specimen shall be coated uniformly by applying several layers over the whole surface until the specified coverage is reached, checked by repeated weighing. Over spray shall be wiped from the exposed faces and edges of the mould. The whole application procedure shall be completed in not more than 2 minutes;

(v) the test specimen and the control specimen shall each be weighed to the nearest gram (m$_3$) and placed immediately on the lowest shelf of the cabinet. After the second pair of specimens has been prepared and weighed, the first pair shall be moved up one shelf and the second pair placed on the lowest shelf. After the third pair of specimens has been prepared and weighed, the first two pairs shall be moved up one shelf and the third pair placed on the lowest shelf;

(vi) the total time for making the specimens, coating the test specimen and placing the pair in the cabinet shall not exceed 2 hours;

(vii) the specimens shall be kept in the cabinet for 72 hours ± 15 minutes after application of the curing compound. Each specimen shall be weighed to the nearest 0.1 g at 24 hours ± 15 minutes and 48 hours ± 15 minutes. Each specimen shall be weighed to the nearest 0.1 g (m$_4$ and m$_5$) at 72 hours ± 15 minutes; and
(viii) the metal tray shall be weighed to the nearest 0.1 g (m₆) and coated with the same quantity ± 0.5 g of curing compound used on the test specimen. The coated tray shall be weighed to the nearest 0.1 g (m₇) and placed in the cabinet for 72 hours ± 15 minutes after application of the curing compound. The tray shall be removed from the cabinet and weighed to the nearest 0.1 g (m₈).

A20.1.6 Calculation

(a) The proportion of solvent lost (V) by the curing compound during the test period shall be calculated from the equation:

\[
V = \frac{(m₇ - m₈)}{(m₇ - m₆)}
\]

where:
- m₆ is the mass of the tray measured in grams;
- m₇ is the mass of the tray after coating measured in grams; and
- m₈ is the mass of the tray after 72 hours in the cabinet measured in grams.

(b) The loss of water from the test specimen (Wₜ) and the loss of water from the control specimen (Wₖ) shall be calculated for each pair of specimens from the following equations:

\[
Wₜ = \frac{(m₃ - m₄) - V(m₃ - m₂)}{(m₂ - m₁)} \times 100\%
\]

\[
Wₖ = \frac{(m₂ - m₅)}{(m₂ - m₁)} \times 100\%
\]

where:
- m₁ is the mass of the mould measured in grams;
- m₂ is the mass of the mould and test or control specimen as appropriate measured in grams;
- m₃ is the mass of the mould and test specimen after coating measured in grams;
- m₄ is the mass of the mould and test specimen after 72 hours in the cabinet measured in grams; and
- m₅ is the mass of the mould and control specimen after 72 hours in the cabinet measured in grams.

(c) The efficiency index (Eₜ) of the curing compound shall be calculated for each test specimen from the equation:

\[
Eₜ = \frac{(Wₖ - Wₜ)}{Wₖ} \times 100\%
\]
The efficiency index \((E)\) of the curing compound shall be calculated as the average of \(E^t\) for the three test specimens.

**A20.1.7 Reporting of Results**

(a) The following shall be reported:

(i) details of the sample of curing compound including identification, source, size, date received and age at test;

(ii) method of compacting the mortar;

(iii) method of applying the curing compound and the type of spray gun used;

(iv) rate of application of the curing compound to the nearest 0.01 L/m²;

(v) duration of the test; and

(vi) efficiency index of the curing compound to the nearest 0.1%.
APPENDIX A20.2

DETERMINATION OF THE DEFLECTION, RECOVERY
AND RESISTANCE TO CRACKING OF PRECAST UNITS

A20.2.1 Scope

This method covers the determination of the deflection and recovery of precast units, including prestressed units, and the resistance to cracking of prestressed units by means of a load test.

A20.2.2 Equipment

(a) The following equipment is required:

(i) rigid supports;
(ii) test loads;
(iii) equipment for measuring the loads applied, readable and accurate to 2% of the specified test load; and
(iv) equipment for measuring the deflection and recovery, readable and accurate to 0.5 mm.

A20.2.3 Procedure

(a) The procedure shall be as follows:

(i) precast unit shall be supported at the specified points of support;
(ii) upward deflection at mid-span due to the prestressing force in a prestressed unit and the deflection at mid-span due to the self-weight of a non-prestressed unit shall be measured;
(iii) specified test load shall be applied at the specified loading points in not less than ten approximately equal increments;
(iv) specified test load shall be maintained for 5 minutes and removed in not less than five approximately equal decrements;
(v) deflection at mid-span shall be measured for each load increment and each load decrement and 5 minutes after the loads have been removed;
(vi) steps (iii) to (v) shall be repeated; and
(vii) load-deflection graphs shall be plotted.
A20.2.4 Reporting of results

(a) The following shall be reported:

(i) details of the precast unit, including place of manufacture;

(ii) the age of the concrete in the precast unit at the time of the test;

(iii) loads applied to the nearest 2% of the specified test load;

(iv) deflections measured to the nearest 0.5 mm;

(v) load-deflection graphs; and

(vi) details of any cracks.
APPENDIX A20.3

DETERMINATION OF THE DISINTEGRATION AND SHRINKAGE, THE RECOVERY VALUE AND REDUCTION IN MASS, AND THE EXTRUSION OF JOINT FILLER

A20.3.1 Scope

This method covers the determination of the disintegration and shrinkage of joint filler, by weathering test, the recovery value and reduction in mass of joint filler by the compression and recovery test, and the extrusion of joint filler by the extrusion test.

A20.3.2 Apparatus

(a) The following apparatus is required:

(i) equipment for measuring the size of the joint filler, readable and accurate to 0.5mm;

(ii) ventilated drying oven;

(iii) water bath;

(iv) watertight weathering test pan with a ribbed bottom and a fitted slotted lid designed to hold 3 specimens of joint filler vertically on edge;

(v) refrigerator;

(vii) equipment for measuring the thickness of the joint filler readable and accurate to 25 μm;

(viii) balance readable and accurate to 0.01 g;

(ix) compression test machine complying with BS 1610 : 1985 with auxiliary platens 100 mm x 100 mm and a minimum thickness of 13 mm; and

(x) extrusion mould open on one side only and rigidly fixed to a base plate. The mould shall be 100 mm x 100 mm (+ 0.5 mm, - 0 mm) internally and shall be of sufficient depth to test the specimen. The mould shall be provided with a close fitting pressure plate which shall fit without binding and with a horizontal measuring dial gauge or device readable and accurate to 25 μm.

A20.3.3 Procedure: weathering test

(a) The procedure for determination of the disintegration and shrinkage by the weathering test shall be as follows:

(i) 3 specimens from the sample shall be prepared, each 115 mm x 115 mm (± 2.5 mm);

(ii) specimens shall be placed in the oven and maintained at a temperature of 55°C, ± 5°C for 7 days. The specimens shall be removed from the oven and immediately immersed in water at room temperature for 24 hours;
(iii) specimens shall be placed in the test pan and the pan shall be filled with water to half the depth of the specimens;

(iv) specimens shall be subjected to 5 cycles of freezing and thawing as follows:

- the test pan and specimens shall be placed in a refrigerator and the water frozen to minus 7°C or below for a period of at least 4 hours after initial freezing; and
- the test pan shall be removed from the refrigerator and placed in the bath without disturbing the specimens for a period of one hour after thawing of the water in the test pan is complete. The water in the bath shall be maintained at a temperature of between 18°C and 38°C;

(v) after the fifth cycle, the specimens shall be removed from the test pan and air dried at room temperature for 48 hours; and

(vi) specimens shall be inspected for evidence of disintegration or shrinkage.

A20.3.4 Procedure: compression and recovery test

(a) The procedure for determination of the recovery value and reduction in mass by the compression and recovery test shall be as follows:

(i) four specimens from the sample shall be prepared, each 100 mm x 100 mm (± 2.5 mm);

(ii) thickness (t₁) of the four specimens shall be measured to the nearest 0.1 mm, and two specimens shall be weighed to within 0.1% of their mass (m₁);

(iii) each specimen shall be subjected to three applications of load in the compression test machine at 24 hour intervals. During each application of load the specimen shall be compressed to 50% of its original thickness at a rate of strain of 1.3 mm per minute. The load required to achieve the compression shall be at least 0.07 N/mm² and shall not exceed 10 N/mm². The load shall be released immediately the specified amount of compression is reached;

(iv) after the third application of load, a recovery period of 30 minutes shall be allowed and the thickness (t₂) of each specimen shall be measured to the nearest 0.1 mm; and

(v) two previously weighed specimens shall be re-weighed to within 0.1% of their mass (m₂).

A20.3.5 Procedure: extrusion test

(a) The procedure for determination of the extrusion by the extrusion test shall be as follows:

(i) one 100 mm x 100 mm (± 0.5 mm) specimen shall be prepared;

(ii) thickness of the specimen shall be measured to the nearest 0.1 mm; and
(iii) specimen shall be placed in the extrusion mould and subjected to one application of load as stated in Section A20.3.4(c). The extrusion at the open side of the mould shall be measured to the nearest 0.1 mm with the gauge or device when the specimen is compressed to 50% of the original thickness and before the load is released.

A20.3.6 Calculation

(a) The recovery value (R) of each specimen shall be calculated from the equation:

\[ R = \frac{t_2}{t_1} \times 100 \%
\]

where:

- \( t_1 \) is the original thickness of the specimen (mm)
- \( t_2 \) is the thickness of the specimen after the third application of load (mm)

(b) The reduction in mass (M) of each specimen shall be calculated from the equation:

\[ M = \frac{(m_1 - m_2)}{m_1} \times 100 \%
\]

where:

- \( m_1 \) is the original mass of the specimen (g)
- \( m_2 \) is the mass of the specimen after the third application of load (g)

A20.3.7 Reporting of Results

(a) The following shall be reported:

(i) type and source of filler;
(ii) any evidence of disintegration or shrinkage as a result of the weathering test;
(iii) recovery values to the nearest 0.5%;
(iv) reductions in mass to the nearest 0.1%; and
(v) extrusion to the nearest 0.1 mm.
APPENDIX A20.4

ROUTINE CHECKS FOR PLANT AND EQUIPMENT

PART 1 BATCHING AND MIXING EQUIPMENT

A20.4.1 Daily Routine

Adjust tare weights and clean weighing dials.
Ensure weighing hoppers empty properly.
Wash-out central mixer drum or pan.

A20.4.2 Weekly Routine

Maintain all hoppers and doors in clean and efficient working order.
Remove any cement or concrete build-up in mixer.
Shake out cement silo filler sock and maintain in efficient working order.
Clean knife edges on weighing equipment.
Check calibration of moisture meter.

A20.4.3 Monthly Routine

Check calibration of all weigh scales.
Check calibration of water meter.
Check calibration of admixture dispenser.

A20.4.4 Quarterly Routine

Inspection and testing of all weigh scales over their complete range.

PART 2 TRANSPORTING EQUIPMENT - MIXER AND AGITATOR UNITS

A20.4.5 Daily Routine

Wash out truck mixer drum.

A20.4.6 Monthly Routine

Check operation of revolution counters.
Check calibration of mixer truck water meter.
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SECTION 21 PRESTRESSING

21.1 GENERAL

21.1.1 Materials for Grout

Materials for grout for prestressing systems shall comply with Section 20 except as stated in this Section.

21.2 DEFINITIONS AND ABBREVIATIONS

21.2.1 Duct

Duct is a void formed in the concrete to accommodate a prestressing tendon.

21.2.2 Prestressing Components

Prestressing components are the components used in a prestressing system, including anchorages, grips, tendon deflectors, couplers, wedges, swages, nuts and other devices used to grip the prestressing tendon.

21.2.3 Prestressing Tendon

(a) Prestressing tendon is:

(i) an individual steel wire, wire strand or alloy steel bar in a duct, or
(ii) an individual steel wire, wire strand or alloy steel bar not in a duct, or
(iii) a group of steel wires or wire strands in a duct used in a prestressing system.

21.2.4 Sheath

Sheath is a tube or lining which is used to form a duct and which is left in place.

21.3 MATERIALS

21.3.1 Prestressing Tendons

(a) Prestressing tendons shall comply with the following:

High tensile steel wire and strand
for the prestressing of concrete : BS 5896

Hot rolled and processed high tensile alloy steel bars
for the prestressing of concrete : BS 4486.

(b) Steel wire and wire strand shall be in coils of sufficiently large diameter to allow the steel wire and wire strand to pay off straight, without any permanent set or bends.

(c) Alloy steel bars shall be straight.
21.3.2 Prestressing Components

(a) Prestressing components shall be a proprietary type reviewed without objection by the Project Manager.

(b) Prestressing anchorages shall comply with BS 4447 and shall allow a minimum of 25 mm cover to cropped ends of prestressing tendons.

21.3.3 Sheaths

(a) Sheaths shall be a proprietary type reviewed without objection by the Project Manager and shall be steel or other material reviewed without objection by the Project Manager. Sheaths shall be rigid and strong enough to retain their shape during fixing and concreting and to withstand forces from the prestressing tendons without damage.

(b) The design of ducts shall allow for grout to be injected from either end. There shall be no sudden changes in the diameter of the duct.

21.3.4 Grout Vents and Taps

Taps for grout vents in ducts shall be a proprietary type reviewed without objection by the Project Manager and shall allow closure of the vents without loss of pressure in the duct. Vents to be used as grout entry points shall be threaded or fitted with screw connectors or other similar devices for connection to grout pumps.

21.3.5 Grout for Prestressing Systems

(a) Grout for prestressing systems shall consist of ordinary Portland cement and water. Sand, PFA and admixtures shall not be used unless otherwise specified in the Contract, or reviewed without objection by the Project Manager.

(b) Grout shall have a minimum crushing strength of 25 MPa at 7 days.

(c) The amount of bleeding of grout shall not exceed 2% in the first 3 hours and shall not exceed 4% in total; the water shall be reabsorbed by the grout during the 24 hours after mixing.

(d) Free expansion of grout shall not exceed 10% at the ambient temperature.

(e) The maximum total chloride content of grout, expressed as a percentage relationship between the chloride ion and the cementitious content by mass in the grout, shall not exceed 0.1%.

(f) Admixtures for grout shall not contain chlorides.

(g) Grout shall have a water cement ratio as low as possible consistent with the necessary workability and under no circumstances shall the water cement ratio exceed 0.45.

21.3.6 Handling of Prestressing Tendons

Prestressing tendons shall not be subjected to rough handling, shock loading or dropping from a height.
21.3.7 Handling of Prestressing Components

Prestressing components shall be handled in accordance with the manufacturers’ recommendations.

21.3.8 Storage of Materials for Prestressing Systems

(a) Each prestressing tendon shall be tagged with a number to identify the coil or bundle number of the prestressing tendon used.

(b) Prestressing tendons and sheaths shall be stored off the ground on level supports and in a manner which will not result in damage or deformation to the materials or in contamination of the materials.

(c) Different types and sizes of prestressing tendons, prestressing components and sheaths shall be stored separately.

(d) Prestressing tendons, prestressing components and sheaths shall not be stored on or adjacent to concrete surfaces which form part of the Permanent Works.

(e) Prestressing tendons, prestressing components and sheaths shall be protected from exposure to conditions which may affect the material.

21.3.9 Surface Condition of Materials for Prestressing Systems

(a) Prestressing tendons, prestressing components and sheaths shall be clean at the time of installation and shall be free from loose mill scale, loose rust, pitting, grease or any substance which in the opinion of the Project Manager is likely to reduce the bond or affect the prestressing tendons, prestressing components, sheaths, concrete or grout chemically. The prestressing tendons, prestressing components and sheaths shall be maintained in this condition until concrete or grout is placed around them.

(b) If the surface condition of the prestressing tendons, prestressing components or sheaths deteriorates such that it does not comply with the requirements stated in Clause 21.3.9(a), the prestressing tendons, prestressing components or sheaths shall be cleaned or dealt with by other methods reviewed without objection by the Project Manager.

21.4 SUBMISSIONS

21.4.1 Particulars of Prestressing Systems

(a) The following particulars of the proposed prestressing systems shall be submitted to the Project Manager for review:

(i) details of the prestressing system, including prestressing tendons, prestressing components, sheaths and tensioning apparatus;

(ii) sequence of prestressing and ends of prestressing tendons from which prestress will be applied;
(iii) calculated values of:
   - each type of loss of prestress;
   - prestressing tendon forces; and
   - extensions of prestressing tendons and details of the method of measuring
     the extensions;

(iv) a certificate showing that the tensioning apparatus has been tested and
calibrated by an agent reviewed without objection by the Project Manager
within a period of two years before the apparatus is to be used;

(v) any alterations to the reinforcement or additional reinforcement required to
allow for primary bursting effects;

(vi) details of corrosion protection required for the prestressing system; and

(vii) details of the format of tensioning schedules and of reports of tensioning
operations, grouting operations and testing of duct friction.

(b) Calculations for loss of prestress due to creep shall be based on the information stated
in the Contract.

21.4.2 Particulars of Prestressing Tendons

(a) The following particulars of the proposed prestressing tendons shall be submitted to
the Project Manager for review:

(i) a certificate from the manufacturer showing the manufacturer's name, the date
and place of manufacture and showing that the prestressing tendons comply
with the requirements stated in the Contract and including details of:

   - cast analysis;
   - diameter, cross-sectional area and unit mass;
   - results of tests for mechanical properties, including the characteristic
     breaking load, characteristic 0.1% proof load, elongation at maximum load,
     relaxation and modulus of elasticity; and
   - results of tests for ductility of prestressing wires.

21.4.3 Particulars of Grout Mix and Grouting Procedure

(a) The following particulars of the proposed grout mix and grouting procedure for
prestressing systems shall be submitted to the Project Manager for review:

(i) water:cement ratio by mass;

(ii) details of mixing and grouting equipment;

(iii) method of quality control during grout injection; and

(iv) details of grouting trials.
21.4.4 Representative Samples of Materials

(a) Representative samples of the following items shall be submitted to the Project Manager at the same time as particulars of the prestressing systems are submitted:

(i) prestressing tendons;

(ii) prestressing components;

(iii) sheaths; and

(iv) grout vents and taps.

21.5 WORKMANSHIP

21.5.1 Installation of Prestressing Systems

(a) Prestressing operations shall be carried out with due regard to the energy stored in a stressed tendon.

(b) Prestressing tendons, prestressing components and sheaths shall be accurately located and maintained in the correct position during all operations; supports shall be placed at a maximum spacing of 600 mm.

21.5.2 Installation of Prestressing Tendons

(a) Prestressing tendons from each batch shall not be installed until testing of the batch has been completed.

(b) Steel wires, wire strands and alloy steel bars which will be tensioned in one operation shall be taken from the same batch.

(c) Individual steel wires and wire strands in the same duct shall not be twisted together. Strands which have become unravelled shall not be used.

(d) Alloy steel bars which have become bent shall not be straightened. Small adjustments for straightness may be made provided the straightening is carried out at the ambient temperature by non-mechanical methods and provided that no force is applied on the threaded portion. Bars which have become bent in the threaded portion shall not be used.

(e) After manufacture, prestressing tendons shall not be welded and heat treatment, work-hardening, galvanizing and other metallic coatings shall not be applied. Prestressing tendons which have been damaged mechanically or by work-hardening or heating shall not be used.

21.5.3 Cutting Prestressing Tendons

Prestressing tendons shall be cut using either a high speed abrasive cutting wheel or a friction saw. Flame cutting shall not be used.
21.5.4 **Joints in Prestressing Tendons**

Joints in prestressing tendons shall be made using proprietary couplers fixed in accordance with the manufacturer's recommendations.

21.5.5 **Use of Prestressing Components**

Prestressing components shall be used in accordance with the manufacturers' recommendations.

21.5.6 **Installation of Sheaths**

At the time of tensioning, sheaths shall be free from dents or other irregularities which may affect tensioning.

21.5.7 **Joints in Sheaths**

(a) Joints in sheaths shall be securely taped to prevent penetration of the duct by concrete or grout. Joints in adjacent sheaths shall be staggered by at least 300 mm.

(b) Where sheaths are used, the number of joints shall be kept to a practicable minimum and sleeve connectors shall be used for jointing.

21.5.8 **Installation of Grout Vents and Taps**

(a) Grout vents and taps shall be provided at the following positions:

(i) all crests of the prestressing tendon profile;

(ii) all low points of the prestressing tendon profile;

(iii) all anchorages; and

(iv) intervals not exceeding 15 m.

(b) Vents shall not be placed at positions where they will be blocked by the prestressing tendons after tensioning.

21.5.9 **Tensioning of Prestressing Tendons**

(a) Apparatus for tensioning prestressing tendons shall impose a controlled total force gradually and shall not induce excessive secondary stresses in the prestressing tendons, prestressing components, structure or element to which prestress is being applied.

(b) Prestressing tendons shall be securely attached to jacks and tensioning apparatus.

(c) Steel wires or wire strands which are tensioned simultaneously shall be approximately the same length between anchorage points.

(d) The force in the prestressing tendons during tensioning shall be measured by direct reading load cells or obtained indirectly from pressure gauges fitted in the hydraulic system. Load measuring devices shall be accurate to within 2%.
(e) The extension of prestressing tendons and any movement of prestressing tendons in the gripping devices shall be measured during tensioning. The elongation of prestressing tendons shall be measured to an accuracy of 2% or 2 mm, whichever is the more accurate.

(f) Tensioning apparatus and load measuring devices shall be calibrated before tensioning starts and at regular intervals reviewed without objection by the Project Manager.

(g) The force in the prestressing tendons shall not be transferred to the concrete until the concrete has reached the specified transfer strength.

21.5.10 Pretensioning

(a) The stress in prestressing tendons shall be fully maintained during the period between pretensioning and transfer of stress. Transfer of stress shall take place gradually to minimise shock or damage to the transmission length and shall be carried out in conjunction with the release of any hold-down and hold-up forces in tendon deflectors.

(b) In the long-line method of pretensioning, locator plates shall be distributed throughout the length of the bed to ensure that the steel wires or wire strands are maintained in the correct positions during concreting. Units which are made in line shall be free to slide in the direction of their length to permit transfer of the prestressing force to the concrete along the whole line.

(c) Moulds used in the individual mould system of pretensioning shall be sufficiently rigid to provide the reaction to the prestressing force without distortion.

(d) Tendon deflectors in contact with pretensioned prestressing tendons of single steel wire or wire strand shall have a radius of at least five times the prestressing tendon diameter for steel wire and at least ten times the prestressing tendon diameter for wire strand. The total angle of deflection shall not exceed 15°. If a system is used such that friction develops between prestressing tendons and tendon deflectors, the friction force shall be determined by a test procedure reviewed without objection by the Project Manager and any necessary allowance shall be made.

21.5.11 Post-tensioning

(a) A tensioning schedule shall be submitted to the Project Manager for review at least 7 days before each post-tensioning operation starts. The schedule shall include the proposed sequence of tensioning the prestressing tendons, the required prestressing loads and the calculated extensions of the prestressing tendons.

(b) Spacers used with post-tensioned steel wire or wire strand which are not tensioned simultaneously shall be sufficiently rigid to ensure that they will not be displaced during successive tensioning operations.

(c) If both ends of the prestressing tendon are free to move, a demonstration shall be carried out before post-tensioning starts to show that all prestressing tendons are free to move in the ducts.

(d) Post-tensioning shall be carried out in such a manner that the stress in the prestressing tendons increases at a gradual and steady rate. The sequence of tensioning prestressing tendons and the ends of prestressing tendons from which prestress will be applied, shall be reviewed without objection by the Project Manager.
(e) For each element of a structure being stressed, post-tensioning of the prestressing tendons shall be carried out until the required prestress to that element has been reached. Tensioning of each prestressing tendon shall be carried out continuously until the required tendon loads or extensions have been reached. If tensioning is stopped for more than 2 days, particulars of any proposals for remedial or other work shall be submitted to the Project Manager for review and tensioning shall not recommence until the remedial or other work has been carried out and reviewed without objection by the Project Manager.

(f) Measurement of extensions shall not commence until any slack in the prestressing tendon has been taken up. If the design permits, the draw-in of prestressing tendons at the non-jacking end shall also be measured. The tensioning shall be applied in increments of load and the extensions shall be measured at each increment. The average measured extension of the prestressing tendons shall be within 5% of the calculated extension and the measured extension of individual prestressing tendons shall be within 10% of the calculated extension.

(g) If the tendon deflector in contact with a post-tensioned prestressing tendon has a radius of less than 50 times the diameter of the prestressing tendon or if the total angle of deflection exceeds $15^\circ$, the loss of strength of the prestressing tendon shall be determined by a test procedure reviewed without objection by the Project Manager and any necessary allowance shall be made.

(h) If the pull-in of the tendons at completion of anchoring is greater than that agreed by the Project Manager, tensioning shall be carried out afresh.

(i) The Project Manager may direct that the force in any strand or wire be tested by re-jacking. The strand or wire shall then be re-anchored at the proper tension.

(j) When the prestressing has been applied, the tendons shall be anchored. The jack pressure shall then be released in such a way as to avoid shock to the anchorage, tendons, or concrete.

(k) Post-tensioned prestressing tendons shall be cut at a distance from the anchorage of at least one diameter or 10 mm, whichever is greater. The tendons shall not be cut until at least 1 day after stressing, if the tendon is to be cut before grouting, or alternatively, at least 3 days after grouting.

21.5.12 Protection of External Prestressing Tendons and Anchorages

External prestressing tendons and anchorages shall be protected in their permanent positions from mechanical damage or corrosion until the permanent protection is applied.

21.5.13 Records of Tensioning Operations

Records of tensioning operations shall be kept by the Contractor on Site and a report shall be submitted to the Project Manager for review within 24 hours of each tensioning operation. Tendons shall not be cut prior to the Project Manager's review without objection of the records of each tensioning operation. The report shall contain the following details:

(a) location of tensioning operations;

(b) coil, heat and bundle numbers of strand used;

(c) date and time of starting and completing tensioning operations;
(d) weather conditions;
(e) technical personnel supervising or carrying out tensioning operations;
(f) prestressing tendon reference numbers;
(g) tensioning apparatus identification;
(h) measured extensions;
(i) pressure gauge or load cell readings;
(j) amount of draw-in; and
(k) concrete temperature.

21.5.14 Grouting Equipment

(a) Grout for prestressing systems shall be mixed by a machine capable of producing a homogeneous colloidal grout and of keeping the grout in slow continuous agitation after mixing and until the grouting operation starts.

(b) Grouting equipment shall be capable of continuous operation at a constant pressure and shall include a system of recirculating the grout when grouting is not in progress.

(c) Grout pumps shall be fitted with a safety valve to prevent the build-up of excessive pressure. The connection of the pump to the duct shall be by a screw connector or other positive method. Baffles to the pump shall be fitted with 1.18 mm sieve strainers; suction circuits shall be airtight.

(d) Grouting equipment shall be thoroughly washed through with clean water after every series of grouting operations and at the end of use each day.

21.5.15 Grouting Effectiveness

Grouting of prestressing tendons shall be effective such that the duct is completely filled and the prestressing tendon is completely surrounded with grout.

21.5.16 Grout Injection

(a) The Contractor shall notify the Project Manager before prestressing tendons are grouted and when required, shall allow the Project Manager sufficient time to inspect the tendons which are to be grouted.

(b) Grouting of prestressing tendons shall be carried out as soon as practicable, and not more than 5 days, after tensioning of the prestressing tendons.

(c) Immediately before grouting starts, the ducts shall be thoroughly washed by pumping clean water through the ducts. The water shall flow through all grout vents. Partial or complete blockage of grout vents shall be cleared before grouting starts. After washing, the ducts shall be blown dry with oil-free compressed air.

(d) Grout shall be used within 30 minutes of mixing unless a retarding agent reviewed without objection by the Project Manager is incorporated in the grout. If a retarding agent is used, the time shall be determined by a test procedure reviewed without objection by the Project Manager.
(e) The grout pressure applied shall be as low as practicable and shall not exceed 1 MPa. Grout shall be injected from the lower end of ducts. Grout injection shall be continuous and steady and shall be at a rate which will avoid grout segregation and trapping air in the duct. Grout shall be allowed to flow from each of the grout vents until its consistency is equivalent to that of the grout injected. After the last grout vent has been closed, the pressure shall be maintained at 0.5 MPa for 5 minutes. The injection vent shall then be closed under pressure.

(f) If there is any blockage or breakdown or if the grout injection is interrupted, the duct shall immediately be thoroughly washed with clean water and blown dry with oil-free compressed air; regrouting shall start as soon as practicable.

(g) The filled ducts shall be protected to the satisfaction of the Project Manager to ensure that:

(i) they are not subjected to shock or vibration within 48 hours of grouting;

(ii) the grout has achieved a strength of not less than 15 MPa before any additional load, arising from the movement of Temporary Works or any construction activity, is applied to concrete containing them; and

(iii) the temperature of the grout does not fall below 3°C for 3 days after its injection.

(h) The level of grout in grout vents shall be inspected and made good as reviewed without objection by the Project Manager. Making good shall not be carried out until at least 2 days after grouting.

(i) Ducts shall not be grouted when the air temperature in the shade exceeds 32°C or is below 3°C. The temperature of the grout at the point of injection shall not exceed 25°C.

(j) Grouting inlet, outlet and intermediate venting points shall be suitably marked to enable the tendon, to which they refer, to be identified.

(k) The Contractor shall radiographically test grouted ducts if directed by the Project Manager.

21.5.17 Records of Grouting Operations

(a) Records of grouting operations for prestressing systems shall be kept by the Contractor on Site and a report shall be submitted to the Project Manager for review within 3 days of each grouting operation. The report shall contain the following details:

(i) location of grouting operations;

(ii) date and time of starting and completing grouting operations;

(iii) weather conditions;

(iv) technical personnel supervising or carrying out grouting operations;

(v) prestressing tendon reference numbers;
(vi) grout mix, including any admixtures;
(vii) grout injection pressure;
(viii) volume of grout used; and
(ix) details of any interruptions and topping up.

21.5.18 Tolerances: Sheaths

The line of sheaths shall be within 5 mm of the specified line as shown on the Employer’s Drawings. Sheathing near concrete surfaces shall not infringe the specified tolerance on concrete cover.

21.6 INSPECTION TESTING AND COMMISSIONING

21.6.1 Trial Mixes for Grout

(a) A trial mix for grout for prestressing systems shall be made to demonstrate that the proposed materials, grout mix and methods of production will produce grout which complies with the specified requirements.

(b) The trial mixes shall be completed at least 10 days before the grout mix is used in the Permanent Works.

(c) The Contractor shall notify the Project Manager before making trial mixes.

(d) Trial mixes shall be made using the materials, grout mix and methods of production which have been reviewed without objection by the Project Manager.

21.6.2 Samples: Trial Mixes for Grout

(a) One sample of grout shall be provided from the trial mix to determine the amount of bleeding and free expansion of the grout. The method of sampling shall be as stated in Clause 21.6.23(b).

(b) One sample of grout shall be provided from the trial mix to determine the crushing strength of the grout. The method of sampling shall be as stated in Clause 21.6.26(b).

21.6.3 Testing: Trial Mixes for Grout

(a) Each sample of grout taken as stated in Clause 21.6.2(a) shall be tested to determine the amount of bleeding and free expansion. The method of testing shall be as stated in Clause 21.6.24(b).

(b) Each sample of grout taken as stated in Clause 21.6.2(b) shall be tested to determine the crushing strength. The method of testing shall be as stated in Clause 21.6.27.

21.6.4 Non-compliance: Trial Mixes for Grout

(a) If the result of any test for amount of bleeding, free expansion or crushing strength of trial mixes for grout does not comply with the specified requirements for the property, particulars of proposed changes to the materials, grout mix or methods of production shall be submitted to the Project Manager for review. Further trial mixes shall be made until the result of every test complies with the specified requirements for the property.
(b) If grouting trials are carried out using a non-complying trial mix, further grouting trials shall be carried out.

21.6.5 Grouting trials

(a) Grouting trials for grout for prestressing systems shall demonstrate that the proposed materials, grout mix, methods of production and methods of construction produce a grouted duct which complies with the specified requirements.

(b) Grouting trials shall be completed at least 7 days before grouting starts.

(c) The Contractor shall notify the Project Manager before carrying out grouting trials.

(d) Grouting trials shall be carried out using the materials, grout mix, methods of production and methods of construction, which have been reviewed without objection by the Project Manager.

(e) The profile of ducts and the method of support for grouting trials shall be submitted to and reviewed without objection by the Project Manager. Vents shall be provided in ducts and tendons shall be pulled tight.

21.6.6 Testing: grouting trials

Three sections selected by the Project Manager shall be cut from the grouted duct and inspected not less than 2 hours after the grout used in the grouting trial has achieved its final set.

21.6.7 Compliance criteria: grouting trials

The sections of grouted duct cut in grouting trials shall be completely filled and the prestressing tendon shall be completely surrounded with grout.

21.6.8 Non-compliance: grouting trials

If the result of any test on sections of grouted duct cut in grouting trials does not comply with the specified requirements for the test, or if in the opinion of the Project Manager any aspect of the grouting procedure as demonstrated by the grouting trial is unsatisfactory, particulars of proposed changes to the materials, grout mix, methods of production or methods of construction shall be submitted to the Project Manager for review and further grouting trials shall be carried out until the result of every test on sections of grouted duct complies with the specified requirements for the test and until in the opinion of the Project Manager every aspect of the grouting procedure is satisfactory. Further trial mixes for grout shall be made unless in the opinion of the Project Manager non-compliance of the grouting trial was not due to the grout mix.

21.6.9 Acceptable Grout Mix

A grout mix which complies with the specified requirements for trial mixes for grout and for grouting trials is defined as an "Acceptable Grout Mix".

21.6.10 Commencement of Grouting

Grouting shall not proceed until the grout mix and grouting procedures have been reviewed without objection by the Project Manager.
21.6.11 Changes in Materials and Methods of Construction

The materials, grout mix, methods of production or methods of construction used to produce an "Acceptable Grout Mix" shall not be changed.

21.6.12 Inspection of Prestressing Systems

The Contractor shall allow sufficient time for the Project Manager to inspect the completed prestressing system before carrying out any work, including concreting and grouting, which will make access to the prestressing system difficult. The Contractor shall notify the Project Manager before carrying out such work.

21.6.13 Testing: Prestressed Units

Testing of prestressed units shall comply with Section 20.

21.6.14 Batch: Prestressing Tendons

A batch of prestressing tendons is any quantity of prestressing tendons of the same type, size and grade, manufactured by the same manufacturer, covered by the same certificates and delivered to Site at any one time.

21.6.15 Samples: Prestressing Tendons

(a) Samples of prestressing tendons shall be provided from each batch of prestressing tendons delivered to Site at least 28 days before installation of the prestressing tendons starts. The number of samples to be provided from each batch shall be as stated in Table 21.1.

(b) The number of specimens in each sample shall be 15.

(c) Each specimen shall be 1.5 metre long and straight.

(d) Each specimen shall be taken from different coils or bars in the batch. The ends of specimens shall be cut square without unravelling of wires and loose mill scale and rust shall be removed by wire brushing before delivery to the laboratory.

Table 21.1: Rate of Sampling Prestressing Tendons

<table>
<thead>
<tr>
<th>Description</th>
<th>Size of batch</th>
<th>No. of samples per batch</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel wire</td>
<td>0 - 50 tonnes</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>exceeding 50 tonnes</td>
<td>1 for each 50 tonnes or part thereof</td>
</tr>
<tr>
<td>Wire strand and alloy steel bar</td>
<td>0 - 100 tonnes</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>exceeding 100 tonnes</td>
<td>1 for each 100 tonnes or part thereof</td>
</tr>
</tbody>
</table>
21.6.16 Testing: Prestressing Tendons

(a) Each specimen of prestressing tendons shall be tested to determine the characteristic breaking load, characteristic 0.1% proof load, elongation at maximum load, diameter, cross-sectional area, unit mass and modulus of elasticity. Each specimen of prestressing wire shall also be tested to determine the ductility.

(b) The method of testing shall be in accordance with the following:

High tensile steel wire and strand for the prestressing of concrete : BS 5896

Hot rolled and hot rolled and processed high tensile alloy steel bars for the prestressing of concrete : BS 4486.

(c) Tests shall be carried out on specimens having a temperature between 5°C and 30°C.

21.6.17 Compliance Criteria: Characteristic Breaking Load, Characteristic 0.1% Proof Load

(a) The standard deviations of the results of tests for characteristic breaking load and characteristic 0.1% proof load, expressed as equivalent stress values, of prestressing tendons shall not exceed the following:

(i) tensile strength : 55 MPa; and

(ii) 0.1% proof stress : 60 MPa.

(b) The statistical interpretation of the test results shall be in accordance with BS 2846:Part 3, Table 3 and BS 2846:Part 4, Table E, both for a one-sided tolerance interval of 0.95 and for a confidence level of 0.95.

21.6.18 Non-compliance: Elongation, Diameter, Cross-sectional Area, Unit Mass, Modulus of Elasticity, Ductility

(a) If the result of any test for elongation at maximum load, diameter, cross-sectional area, unit mass, modulus of elasticity or ductility of prestressing tendons does not comply with the specified requirements for the property, one additional sample shall be provided from the same batch and additional tests for the property shall be carried out.

(b) The number of specimens in the additional sample shall be 15.

(c) The batch shall be considered as not complying with the specified requirements for the property if the result of any additional test does not comply with the specified requirements for the property.

21.6.19 Testing: Duct Friction

(a) Unless otherwise stated in the Contract, the Contractor shall test, at an early stage of the Contract, two in-place tendons in order to accurately determine friction loss.

(b) Prestressing tendons shall be tensioned from one end and the tendon force shall be measured at both the jacking and non-jacking ends.
(c) The tendon force at the non-jacking end shall be measured by direct-reading load cells or by a dummy jack of a type reviewed without objection by the Project Manager. A direct-reading load cell or a dummy jack is considered to be suitable as a load-measuring device. The load-measuring device shall be sufficiently rigid to ensure that the movement of the prestressing tendon at the non-jacking end under the specified tendon force is not excessive. The deflection of the load-measuring device shall be measured to an accuracy of 0.5 mm. A load-measuring device with a deflection exceeding 10 mm under the maximum load shall not be used.

(d) The prestressing tendon shall be tensioned to the specified tendon force in equal increments and the tendon extensions at the jacking end and the tendon force and tendon movement at the non-jacking end shall be measured to within 5 mm. The number of load increments shall be suited to the tensioning operation but shall be at least five.

21.6.20 Compliance Criteria: duct Friction

The force at the non-jacking end of the prestressing tendon determined in the duct friction test shall be within +10% and -5% of the calculated value.

21.6.21 Records of duct Friction Tests

(a) Reports of duct friction tests shall be submitted to the Project Manager for review within 3 days of each test. The report shall contain the following details:

(i) details stated in Clauses 21.4.1 and 21.4.2;

(ii) prestressing tendon reference numbers;

(iii) graph showing tendon forces at jacking end against tendon forces at non-jacking end; and

(iv) comparison between the calculated tendon forces at the non-jacking end and the measured values.

21.6.22 Batch: Grout for Prestressing Systems

A batch of grout for prestressing systems is any quantity of grout produced in one cycle of operation of a mixer.

21.6.23 Samples: Bleeding and Free Expansion of Grout

(a) For each grout mix one sample of grout shall be provided from each 25 batches of grout, or from the amount of grout produced in one day, whichever is the lesser, to determine the amount of bleeding and free expansion of the grout.

(b) Samples shall be provided and testing shall commence within one hour after the grout has been mixed. Samples shall be protected from rain before the tests.


(a) Each sample of grout taken as stated in Clause 21.6.23 shall be divided into three specimens; each specimen shall be tested at a temperature of 20°C to determine the amount of bleeding and free expansion.

(b) A portion of each specimen shall be placed in a covered cylinder with a diameter of 100 ± 10 mm, to a depth of 100 ± 5 mm and the amount of bleeding and free expansion measured by a scale fixed to the outside of the cylinder.
21.6.25 Non-compliance: Bleeding and Free Expansion of Grout

If the result of any test for amount of bleeding or free expansion of grout for prestressing systems does not comply with the specified requirements for the property, particulars of proposed changes to the materials, grout mix or methods of production shall be submitted to the Project Manager for review. Upon review further trial mixes shall be made and further grouting trials shall be carried out.

21.6.26 Samples: Crushing Strength of Grout

(a) For each grout mix one sample of grout shall be provided from each 25 batches of grout, or from the amount of grout produced in a day, whichever is the lesser, to determine the crushing strength of the grout.

(b) Samples shall be provided not more than 1 hour after the grout has been mixed and shall be protected from rain before test cubes are made.

21.6.27 Testing: Crushing Strength of Grout

(a) Two 100 mm test cubes shall be made from each sample of grout taken as stated in Clause 21.6.26 (a). Each pair of test cubes shall be tested to determine the crushing strength at 7 days.

(b) The method of making, curing and testing the test cubes, and the calculation of the test results, shall be as stated in Clause 20.8.12(b), (c), (d) and (e), except that compaction of the grout is not required.

21.6.28 Non-compliance: Crushing Strength of Grout

If the result of any test for crushing strength of grout for prestressing systems does not comply with the specified requirements for crushing strength, particulars of proposed changes to the materials, grout mix or methods of production shall be submitted to the Project Manager for review. Upon review further trial mixes shall be made and further grouting trials shall be carried out.
SECTION 22  STEELWORK

22.1  GENERAL

(a) Allowances shall be made for the deformation due to permanent loads and the process and sequence of fabrication, erection and construction such that steelwork is completed to within the specified tolerances.

(b) The compatibility of the dimensions and setting-out data of steelwork shall be verified by the Contractor before the materials for steelwork are ordered.

22.2  RELEVANT CODES AND STANDARDS

22.2.1  Steelwork Standards

The use of steelwork shall comply with the Code of Practice for the Structural Use of Steel, Hong Kong. BS 5950:Part 1 & 2:1990 may be used provided the specific requirements as outlined in the Practice Note for Authorized Persons and Registered Structural Engineers (PNAP) No. 160 apply.

22.2.2  Protection of Steelwork

Protection of steelwork against corrosion shall comply with BS 5493.

22.2.3  Amendments to BS 5400 : Part 6

The following amendments shall apply to BS 5400:Part 6:

(a) Contents page :
    Delete '6.3.1 General'.

(b) Page 2, Clause 3.1.4.1, lines 5, 8 and 14:
    Delete 'C of DD21' and insert 'L1 of BS 5996'.

(c) Page 2, Clause 3.1.4.1, line 10 and Clause 3.1.4.2, line 3:
    Delete 'DD21' and insert 'BS 5996'.

(d) Page 3, Clause 4.2.1, line 2:
    Delete '4.4.2' and insert '4.2.2'.

(e) Page 3, Clause 4.3.3(e), line 1:
    Delete line 1 of text and insert 'the hardness of the edge is reduced to less than 350 HV 30 of BS 427 by a suitable heat treatment'.

(f) Page 4, Clause 4.7.1, paragraph 2, line 4:
    Delete '23 of BS 5135' and insert '20 of BS 5135'.
Page 5, Clause 4.14:

Delete and insert:

'The Contractor shall determine the dead load camber of beams required to comply with Section 22.1(a) of this Specification. The camber of plate girders shall be formed by either of the two following alternatives, whichever is stated in the Contract:

Type A cambering: camber introduced by welding the flanges pressed against a web plate cut to a smooth cambered profile; or

Type B cambering: camber introduced by connecting straight sections of girder with a change of slope at their junctions.

Type A camber shall be used if the alternative to be used is not stated in the Contract.

With Type B cambering the junctions shall not be positioned at bolted connections.'

Page 6, Clause 5.2.2, line 2:

Delete 'DD21' and insert 'BS 5996'.

Page 7, Clause 5.5.2, paragraph 3, line 3:

Delete 'grider' and insert 'girder'.

Page 9, Clause 6.3.1:

Delete Clause 6.3.1.

Page 15, Table 5, column 3, Member component 4:

Delete 'G=0' and insert 'G=D'.

22.3 MATERIALS

22.3.1 Structural Steel

(a) Structural steel shall comply with BS 4360, including Clause B7 at Appendix B, and with BS 5950:Part 2, Section 2.1 with the incorporation of specific requirements outlined in PNAP 160.

(b) Hot rolled sections complying with BS 4:Part 1, BS 4848:Part 2, BS 4848: Part 4 or BS 4848:Part 5 shall not be replaced with sections complying with other standards unless reviewed without objection by the Project Manager.

22.3.2 Cold formed Sections

(a) Steel for cold formed sections shall comply with BS 1449:Part 1 with the quality grades as stated in the Contract.

(b) Steel for cold formed hollow sections shall comply with BS 6363 with quality grades as stated in the Contract.
(c) Pre-galvanized steel sheet shall comply with BS 2989 with quality grades as stated in the Contract.

22.3.3 Maximum Carbon Equivalent

Steel used in built-up welded assemblies or at welded connections shall have a carbon equivalent value complying with Table 2 of BS5135.

22.3.4 Steel for Shear Connectors

Steel for headed stud type shear connectors shall have a yield stress of at least 385 N/mm$^2$ and an ultimate tensile strength of at least 450 N/mm$^2$. Steel for other types of shear connectors shall comply with BS 4360.

22.3.5 Bolts, Screws, Nuts and Washers

(a) Bolts, screws and nuts shall comply with the British Standards and strength grades stated in Table 22.1 unless stated otherwise in the Contract.

(b) Washers for high strength friction grip bolts and nuts shall comply with the following:

(i) high strength friction grip bolts and associated nuts and washers for structural engineering:
   - general grade : BS 4395:Part 1;
   - higher grade bolts and nuts and general grade washers : BS 4395:Part 2; and
   - higher grade bolts (waisted shank), nuts and general grade washers : BS 4395:Part 3;

(ii) load indicating washers for high strength friction grip bolts and nuts shall be "Coronet" type manufactured by Cooper and Turner or equivalent reviewed without objection by the Project Manager; and.

(iii) plain washers for other bolts, screws and nuts shall comply with BS 4320; tapered washers for other bolts, screws and nuts shall comply with BS 3410; spring washers for other bolts, screws and nuts shall comply with BS 4464.

(c) The surface finish for bolts, screws, washers and nuts shall comply with the following:

(i) galvanized - BS 729;

(ii) zinc or cadmium plated - electroplating shall comply with either:
   BS 3382 for bolts up to and including 20 mm diameter; or
   BS 1706 Class A for bolts over 20 mm diameter; and

(iii) sherardized - BS 4921.
22.3.6 Welding Consumables

(a) Welding consumables used in metal-arc welding of grades of steel complying with BS 4360 shall comply with BS 5135. Welding consumables used in the fusion welding of steel castings shall comply with BS 4570. Welding consumables used in metal-arc welding of austenitic stainless steels shall comply with BS 4677.

(b) Welding consumables and the procedures used shall be such that the mechanical properties of the deposited weld metal shall not be less than the respective minimum values of the parent metal being welded.

(c) Welding consumables used with grades of steel other than those complying with BS 4360 shall be such that the performance requirements stated in BS 5400:Part 6, Table 1 or BS 5950:Part 2, Table 1 as appropriate are achieved.

(d) Electrodes for welding Grade 50 and Grade S355 steels shall be capable of depositing no more than 15 ml of diffusible hydrogen per 100 g of deposited weld metal, as defined in BS 639.

(e) Covered electrodes for manual metal arc welding shall comply with BS 639.


(g) Electrodes shall be kept in unbroken packets in accordance with BS 5135. Any drying or baking of consumables before issue shall be carried out in accordance with the manufacturer's recommendations.

22.3.7 Rolled Steel Pins

Rolled steel pins, including those made from slabs, shall comply with BS 970:Part 1 or BS 4360, Grades 43, 50 or 55.

Table 22.1: British Standards And Strength Grades For Bolts, Screws And Nuts

<table>
<thead>
<tr>
<th>Type of bolts, screws and nuts</th>
<th>British Standard</th>
<th>Strength grade of bolt</th>
<th>Strength grade of nut</th>
</tr>
</thead>
<tbody>
<tr>
<td>High strength friction grip bolts and nuts</td>
<td>BS 4395:Part 1</td>
<td>General grade</td>
<td>as specified in BS4395 : Part 1</td>
</tr>
<tr>
<td>Precision bolts, screws and nuts</td>
<td>BS 3692</td>
<td>4.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Cup head and countersunk head bolts, screws and nuts</td>
<td>BS 4933</td>
<td>4.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Black bolts, screws and nuts</td>
<td>BS 4190</td>
<td>4.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Other types of bolts, screws and nuts</td>
<td>BS 4190</td>
<td>4.6</td>
<td>4.0</td>
</tr>
<tr>
<td>Hexagon socket screws</td>
<td>BS 4168:Part 1</td>
<td>12.9</td>
<td>12.0</td>
</tr>
</tbody>
</table>

22.3.8 Steel Castings and Cast Steel Pins

Carbon manganese steel castings shall comply with BS 3100.
22.3.9 Steel Forgings and Forged Steel Pins

Steel forgings and forged steel pins shall comply with BS 29.

22.3.10 Stainless Steel

(a) Wrought stainless steel shall comply with BS 970:Part 1, Grade 316 S 16.
(b) Flat rolled stainless steel shall comply with BS 1449:Part 2, Grade 316 S 16 in the softened condition.
(c) Stainless steel tubes shall comply with BS 6323:Part 1 and BS 6323:Part 8, designation LW 23 GZF(S).
(d) Stainless steel bolts and nuts shall comply with BS 6105, steel Grade A4 and property class 80. Stainless steel washers shall comply with BS 1449:Part 2, Grade 316 S 31 in the softened condition. The dimensions and tolerances of bolts and nuts shall comply with BS 3692. The dimensions and tolerances of tapered washers shall comply with BS 3410 and the dimensions and tolerances of flat washers shall comply with BS 4320, Form C.

22.3.11 Grout for Column Bases

(a) Grout for bedding steel bases and for filling bolt pockets and pocket bases shall be cementitious materials based on OPC and shall have the same or greater grade strength as the surrounding foundation concrete. The grout shall contain a non-metallic expanding admixture and shall have a total chloride content of not more than 0.1% by mass of cement.
(b) Grout for bedding steel bases and for filling bolt pockets shall not contain high alumina cement and shall be a proprietary type where stated on the Employer's Drawings or reviewed without objection by the Project Manager and shall be suitable for filling the space by pouring under a suitable head. The proportions of the grout shall be in accordance with the manufacturer's recommendations.
(c) A dry packed mortar may be used for bedding steel bases which exceed 75 mm thick. The mortar shall be cementitious material having the same grade strength of the surrounding concrete and be suitable for thorough ramming against supports such that the space is completely filled.
(d) Grout for filling pocket bases shall be a mix reviewed without objection by the Project Manager with a nominal maximum aggregate size of 10 mm and have the same grade strength as the surrounding concrete.

22.3.12 Lubricant for Nut Threads of HSFG Bolts

Lubricant for lubricating nut threads of HSFG bolts shall be a wax based type reviewed without objection by the Project Manager. Machine oil and other free flowing lubricants shall not be used.

22.3.13 Paint for Steelwork

(a) Unless otherwise stated in the Contract paint for steelwork shall comply with BS 5493, Section 2, Table 4. Organic zinc-rich paint shall comply with BS 4652. Lead-based paint shall not be used for finishing coats.
(b) Paint shall be supplied in sealed containers of not more than 5 litres capacity. Each container shall be marked on the side to show the following:

(i) the name of the manufacturer;
(ii) the paint manufacturer’s reference number;
(iii) intended purposes, type of pigment and binder;
(iv) batch number, date of manufacture, expiry date and pot life; and
(v) colour, gloss, drying times and flash point.

### 22.3.14 Marking Steelwork

(a) All steelwork shall be clearly marked for identification and erection purposes as:

(i) identification: The Contractor shall identify all steel elements in accordance with BS 4360 or BS EN 10025 as applicable, indicating grade, cast number and manufacturer’s identification mark;

(ii) Grade 50 and Grade S355 steel: In addition to marking in accordance with BS 4360 or BS EN 10025 the Contractor shall mark steel with a continuous pale blue water paint line. The Contractor shall mark immediately, with light blue water paint, any part cut from Grade 50 or S355 steel which does not have a light blue marking;

(iii) cold worked steel: The Contractor shall mark cold worked areas of steel members with orange water paint;

(iv) marking for erection purposes: The Contractor shall tag, hard stamp or pencil weld each member with an individual identification mark, which can not be obliterated by surface coatings. The Contractor shall submit a Contractor’s Drawing identifying markings and indicating the positions of members in structures; and

(v) permanent identification: The Contractor shall supply and fix to each structure after erection, a brass identification plate. The plate shall indicate with lettering not less than 15 mm high, etched or punched to a depth not less than 1.5 mm, the following:

- grade of steel in structure; and
- date of fabrication.

### 22.3.15 Handling and Transport of Steelwork

(a) Steelwork shall not be subject to rough handling, shock loading or dropping from a height.

(b) During handling and transport of coated steelwork, the steelwork shall be separated from wires and lashings by rubber padding in such a manner that the coatings are not damaged or discoloured. The Contractor shall take such measures to prevent permanent distortion such as stiffening free ends and protecting machined surfaces.

(c) Steelwork shall not be lifted from the painting bed until the last applied coating is sufficiently dry or cured for handling.
(d) Rivets, bolts, nuts, washers, screws and small plates and articles shall be packed in containers marked to identify the contents.

(e) For road transport the Contractor shall:
   (i) provide intermediate supports to which a component can be tied with strops to prevent oscillation; and
   (ii) sit components on softwood supports covered with soft clean pads.

(f) For sea transport the Contractor shall:
   (i) containerise all steelwork;
   (ii) pack containers so that no components touch;
   (iii) use softwood with soft padding and man-made fibre ropes and strops to prevent movement and contact;
   (iv) bag fasteners and accessories;
   (v) bundle small components and prevent contact; and
   (vi) chromate dip galvanized steel, which is not to be overcoated, when it will be containerised for longer than three weeks.

22.3.16 Storage of Steelwork

(a) Steelwork shall be stored off the ground on level supports in well drained areas in a manner which will not result in damage or deformation to, or in contamination of, the steelwork or coatings. Packing shall be placed between steelwork which is stacked.

(b) Covered places in which steelwork is stacked shall be ventilated.

(c) Different types and sizes of steelwork shall be stored separately.

(d) Steelwork shall not be stored on or adjacent to concrete surfaces which form part of the Permanent Works.

(e) Steelwork shall be protected from exposure to conditions which may affect the steelwork or coatings.

(f) Wet paint films, steelwork surfaces which are to be primed or overcoated and joint surfaces which are to be assembled shall be protected from exposure to conditions which may affect the film or surface.

(g) Except as stated in Section 22.3.16(h) and (i), steelwork shall be stored in an enclosed workshop and protected from conditions which may affect the steelwork after it has been cleaned as stated in Section 22.5.12 until the following times:
   (i) when the second undercoat to painted steelwork has hard dried;
   (ii) when the coating process to galvanized, electroplated or metal sprayed steelwork has been completed;
(iii) when the sealer to metal sprayed and sealed steelwork has been completely absorbed; and

(iv) when the first undercoat to metal sprayed and painted steelwork has hard dried.

(h) Primed steelwork surfaces may be exposed outside the enclosed workshop for a period not exceeding two weeks.

(i) Micaceous iron oxide undercoats to steelwork may be exposed outside the enclosed workshop for the minimum period necessary to move the steelwork from one part of the workshop to the other. Undercoated surfaces shall be covered when the steelwork is being moved.

(j) All painted steelwork shall be checked for undercoat contamination prior to the application of subsequent coats.

(k) Steel members shall be stored and stacked such that markings are clearly visible.

22.3.17 Storage of Paint

Paint and associated materials shall be stored in sealed containers marked as stated in Section 22.3.13(b) and protected from exposure to conditions which may affect the material. The materials shall be stored in accordance with the manufacturers' recommendations and shall not be used after the recommended expiry date. The materials shall be stored in a locked store.

22.3.18 Metal Coatings to Steelwork

(a) Galvanized coatings shall be applied by hot-dip galvanizing in accordance with BS 729. The coating thickness shall comply with BS 729, Table 1.

(b) Sherardized zinc coatings shall comply with BS 4921, Table 1, Class 1.

(c) Sprayed zinc and aluminium coatings shall comply with BS 2569:Part 1. The nominal coating thickness shall be 100 µm. The sprayed metal shall be pre-treated with product CP1 and sealed with product CP3C in accordance with BS 5493.

(d) Electroplated zinc and cadmium coatings on threaded components with a diameter not exceeding 36 mm shall comply with BS 3382:Parts 1 and 2. The coating thickness shall be at least 5 µm.

(e) Metal coatings which will be overcoated with paint shall not be passivated and shall be treated in accordance with the manufacturer's recommendations for the specific coating system selected.

(f) Allowance for the thickness of the metal coating shall be made in the sizes of the threads of metal coated threaded components. Nuts shall not be tapped oversize by more than 0.4 mm. Metal coated HSFG bolts and nuts shall not be tapped oversize.

(g) Damaged areas of metal coatings shall be rubbed down to remove excessive roughness, cleaned and made good with a compatible coating of a type reviewed without objection by the Project Manager.
(h) Metal coatings required on part of a component shall be completed before the rest of the component is painted.

(i) Chromium plating shall comply with BS 4641.

22.3.19 Painting Systems for Steelwork

(a) The painting system to be used for steelwork shall be as stated in the Contract.

(b) The different types of paints within each painting system shall be compatible with each other and shall be manufactured by the same manufacturer. Successive coats in a painting system, including stripe coats, shall be in contrasting colours to aid identification.

22.4 SUBMISSIONS

22.4.1 Particulars of Steel

(a) The original or certified true copy of the manufacturer's mill certificates for steel shall be submitted to the Project Manager for review in accordance with BS 4360, Clause 12 and Appendix B 6.

(b) The mill certificates shall be submitted to the Project Manager not more than 7 days after the steel has been delivered to the place of fabrication.

22.4.2 Particulars of Shop Drawings

(a) Two sets of Contractor’s Drawings of the steelwork shall be submitted to the Project Manager for review at least 6 weeks before fabrication of the steelwork starts. These Contractor’s Drawings shall show details of the following:

(i) steelwork and welds, including any stud welds, marked with the relevant welding procedures;

(ii) joints or non-standard welds proposed by the Contractor;

(iii) locations and method of removal of any temporary welded attachments proposed by the Contractor;

(iv) edges of steelwork complying with BS 5400:Part 6 to be formed by flame cutting or shearing procedures complying with BS 5400:Part 6, Clause 4.3.3(a), (d) or (e) with the edges marked with the procedures to be used;

(v) parts of steelwork complying with BS 5400:Part 6 to be worked by hot processes complying with BS 5400:Part 6, Clause 4.8, 4.9 or 4.10 with the parts marked with the processes to be used; and

(vi) details of holding down bolts and fittings to be cast into the concrete or masonry.

(b) Fabrication work shall not commence until the Contractor’s Drawings and the associated method statements have been reviewed without objection by the Project Manager.
22.4.3 Particulars of Method of Erecting Steelwork

(a) The following particulars of the proposed method of erecting steelwork shall be submitted to the Project Manager for review:

(i) sequence and method of erection of steelwork;

(ii) method of lifting and handling the components;

(iii) method of preventing damage to protective coatings on steelwork during handling;

(iv) procedure for aligning, levelling and plumbing steelwork, including temporary supports and method of making beddings for column bases;

(v) sequence of casting concrete bonded to the steelwork; and

(vi) calculations of erection stresses.

22.4.4 Welder Certificates

(a) Certificates endorsed by an independent HOKLAS accredited inspecting authority shall be submitted to the Project Manager for review to show that each welder has been approved in accordance with BS 4570, BS 4871:Part 1 or BS 4872:Part 1 as appropriate. The extent of approval of the welder shall be appropriate to the categories of welds which he will carry out.

(b) The welder certificates shall be submitted at least 2 weeks before fabrication of the steelwork starts.

22.4.5 Particulars of Welding Procedures

(a) The following particulars of the proposed welding procedures shall be submitted to the Project Manager for review:

(i) welding procedures in accordance with BS 5135, Clause 20 for each type and size of weld;

(ii) documentation endorsed by an independent HOKLAS accredited inspecting authority to show that the welding procedure has complied with the procedure trial requirements stated in the Contract in previous tests, or that the welding procedure for steel castings complies with the exemption criteria stated in BS 4570, Clause 20.1.1; and

(iii) records of approval tests as stated in Clause 22.6.7 (a) if procedure trials are required under Clause 22.6.1 (a).

22.4.6 Particulars of Stud Welding, Flame Cutting and Shearing Procedures

(a) The following particulars of the proposed stud welding, flame cutting and shearing procedures for steelwork complying with BS 5400:Part 6 shall be submitted to the Project Manager for review:

(i) procedures for stud welding, flame cutting and shearing processes complying with BS 5400:Part 6, Clause 4.3.3(a), (d) or (c);
(ii) documentation endorsed by an independent HOKLAS accredited inspecting authority to show that the stud welding, flame cutting or shearing procedure has complied with the procedure trial requirements stated in the Contract in previous tests; and

(iii) report of procedure trials as stated in Clause 22.6.7 (a) if procedure trials are required under Clause 22.6.1 (a).

22.4.7 Particulars of Vent Holes for Galvanizing

Particulars of the method of plugging vent holes required for hot-dip galvanizing hollow or box sections shall be submitted to the Project Manager for review.

22.4.8 Particulars of Method of Non-destructive Testing

Particulars of the proposed method for carrying out non-destructive testing on welds shall be submitted to the Project Manager for review.

22.4.9 Particulars of Inspecting Authority and Testing Consultant

(a) The name of the proposed independent HOKLAS accredited inspecting authority endorsing welder certificates and records of approval tests for welding procedures shall be submitted to the Project Manager for review.

(b) The name of the proposed testing consultant stated in Section 22.6.13 shall be submitted to the Project Manager for review.

22.4.10 Particulars of Paint

(a) The following particulars of the proposed paints and associated products shall be submitted to the Project Manager for review:

(i) name of manufacturer;

(ii) duplicate copies of the manufacturer's data sheets including temperature, humidity, method of application and other conditions at the workshop or on Site under which the paint is to be applied; and

(iii) manufacturer's product specifications, product range and technical information.

22.4.11 Representative Samples of Materials

(a) A representative sample of blast cleaned steel plate shall be submitted to the Project Manager for review. The sample shall be 150 mm x 150 mm x 6 mm and shall be enclosed in a sealed, colourless, transparent wrapping. The grade of steel and the method of blasting shall be representative of those which will be used in the Permanent Works.

(b) Two representative samples of painted metal plates for each painting system shall be submitted to the Project Manager for review. Each plate shall be 150 mm x 75 mm x 1 mm and shall have smooth edges and 10 mm corner radii. The plates shall be brush cleaned and painted on one face with the painting system in such a manner that each coat is stepped back from the underlying coat in equal strips. The degree of gloss of the finishing coat shall be reviewed without objection by the Project Manager.
(c) Representative samples of each type of nut, bolt, washer, stud and rivet shall be submitted to the Project Manager for review.

22.5 WORKMANSHIP

22.5.1 Fabrication of Steelwork

Fabrication of steelwork shall comply with BS 5400:Part 6, Clauses 4.1 to 4.16 or BS 5950:Part 2, Sections 3 and 4 as appropriate except as stated in Sections 22.5.2 to 22.5.11 and 22.6.12.

22.5.2 Welding, Heating and Cutting

(a) Welding shall only be carried out by welders who possess a valid welding certificate for the appropriate category of welding. A welder shall cease to carry out welding if any of the circumstances stated in BS 4570, Clause 21.1, BS 4871:Part 1, Clause 11 or BS 4872:Part 1, Clause 6 as appropriate occur.

(b) Pre-setting, pre-bending, skip welding, back-step techniques and other measures shall be taken as necessary to counteract shrinkage or distortion due to welding, gouging, thermal cutting or heat treatment.

(c) Butt welds shall be complete penetration butt welds made between fusion faces.

(d) Butt welds in each component part shall be completed before the final assembly of built-up assemblies.

(e) To ensure full throat thickness at the ends of butt welds run-on and run-off plates shall be used. These plates shall comply with the following:

   (i) identical material to that being welded;

   (ii) prepared in the same manner as the parts being joined;

   (iii) removed by cutting after completion of welding;

   (iv) the surfaces where plates were attached shall be ground smooth and inspected for cracks;

   (v) welding of austenitic stainless steel shall be carried out in accordance with BS 4677;

   (vi) temporary welded attachments for either fabrication or erection shall comply with BS 5135 and shall be reviewed without objection by the Project Manager;

   (vii) welding, heating or thermal cutting processes which give off toxic or irritant gases shall not be used;

   (viii) tack welds shall comply with BS 5135;

   (ix) materials, procedures, fixing and equipment for shear studs shall be in accordance with the manufacturer's recommendations; and

   (x) slag shall be removed by light hammering, wire brushing or other methods which will not deform the surface of the weld.
22.5.3 Length of Bolts

The length of HSFG bolts shall comply with BS 4604:Part 1 or BS 4604:Part 2 as appropriate. The length of bolts complying with BS 3692, BS 4190 and BS 4933 shall be such that the end of the bolt shall project above the nut by at least one clear thread, but by not more than one nominal bolt diameter, and at least one clear thread plus the thread run out is clear between the nut and the unthreaded shank of the bolt, after tightening.

22.5.4 Length of Threads

The length of threads on bolts shall be determined in accordance with BS 3692, BS 4190, BS 4395:Part 1, BS 4395:Part 2, BS 4395:Part 3 or BS 4933 as appropriate. If additional locknuts or other nuts are specified, the thread length shall be increased by one nominal bolt diameter for each additional nut.

22.5.5 Bolt Holes

(a) Bolt holes shall be formed by drilling, punching or reaming.

(b) Except in steel base plates or where otherwise noted on the Employer's Drawings the size of holes for ordinary bolts shall be of diameter not more than 2 mm greater than the diameter of the bolts for bolts up to 24 mm diameter, and not more than 3 mm greater than the diameter of the bolt for bolts over 24 mm diameter.

(c) Holes for HSFG fasteners shall comply with BS 4604.

(d) Bolt and vent holes in hollow sections shall be sealed to prevent the ingress of moisture. Where not specified on the Employer's Drawings the method shall be proposed on the Contractor’s Drawings submitted in accordance with Section 22.4.2.

22.5.6 Use of Nuts

(a) Nuts shall not be used with bolts or screws which comply with a different standard.

(b) Bolt assemblies shall be in such a condition immediately before installation that the nut turns freely on the bolt.

(c) Nuts in galvanized assemblies shall be re-tapped after galvanizing.

(d) Nuts shall be secured in connections subject to vibration or reversal of stresses to prevent loosening. If not shown on the Employer's Drawings, the proposed method shall be shown on the Contractor’s Drawings submitted in accordance with Section 22.4.2.

22.5.7 Use of Washers

(a) Washers for HSFG bolts shall be provided in accordance with BS 4604:Part 1 or BS 4604:Part 2 as appropriate. Washers shall be provided for bolts complying with BS 3692, BS 4190 and BS 4933 under the nut or bolt head, whichever is rotated during tightening, if the parts to be connected are to be coated with protective coatings before assembly. Washers shall be provided under the nuts and heads of bolts in oversized and slotted holes.

(b) Tapered washers shall be used under bolt heads and nuts bearing on surfaces sloping 3° or more from a plane at right angles to the bolt axis.
(c) Bolt assemblies containing spring washers shall be tightened until the spring washer is completely flattened.

22.5.8 Tightening of Bolts

Bolts shall be tightened in accordance with BS 5950:Part 2 and in such a manner that the contact surfaces of permanent bolted joints are drawn into close contact.

22.5.9 Tightening of HSFG Bolts

(a) The degree of preliminary tightening of bolts and nuts complying with BS 4395:Part 1 which are tightened by the part turn method shall be torque controlled. The tightening equipment for preliminary tightening shall be calibrated with a bolt load meter. The value of bedding torque for the preliminary tightening shall be within 10% of the values stated in Table 22.2.

(b) Bolts and nuts at each joint with bolts or washers with load indicating devices shall be initially tightened to bring the faying surfaces into close contact over the full area. The range of the average gap after initial tightening shall be reviewed without objection by the Project Manager. The bolts and nuts shall be re-tightened if necessary to close the average gap back to the agreed range. After all bolts and nuts at the joint have been initially tightened, the bolts and nuts shall be finally tightened to attain the shank tension stated in BS 4604:Part 1 or BS 4604:Part 2 as appropriate. The range of average gap corresponding to the required shank tension shall be established for each batch as defined in BS 4395:Part 1, BS 4395:Part 2 or BS 4395:Part 3 as appropriate by testing at least three bolt, nut and washer assemblies in a bolt load meter and shall be reviewed without objection by the Project Manager. The average gap after final tightening shall be within the established range.

(c) The threads of nuts for HSFG bolts which are to be tightened by the part turn method or the load indicating method shall not be lubricated unless reviewed without objection by the Project Manager. If the use of lubricant is permitted in the part turn method, the bedding torque shall be established by a bolt load meter and shall be reviewed without objection by the Project Manager. The lubricant shall be applied at the place of manufacture and shall only be applied to the nut threads. The bearing surfaces of the nuts and the faying surfaces shall not be contaminated with the lubricant.

(d) The bolt load meter for measuring bolt shank tension in the part turn, torque control or load indicating methods of tightening shall be calibrated by a laboratory reviewed without objection by the Project Manager before tightening of bolts and nuts starts and at regular intervals reviewed without objection by the Project Manager. During re-calibration, a replacement calibrated bolt load meter shall be provided on Site. Calibration results shall be submitted to the Project Manager for review at least one week before the bolt load meter is used.

(e) If after tightening, a bolt or nut is slackened-off for any reason, the complete bolt assembly shall be discarded and not re-used in the Permanent Works.

(f) The faying surfaces for HSFG fasteners shall be in accordance with the following:

   (i) mill scale shall be removed;

   (ii) free from distortion, deformities or contaminants which may reduce the slip factor below the design value; and
(iii) deformed surfaces shall be machined flat and tested in accordance with BS 4604 to determine the slip factor after machining.

(g) Following complete assembly of all bolted connections, the fit and tightness of the bolts shall be checked at locations reviewed without objection by the Project Manager.

(h) Prior to Site painting of HSFG bolted connections the following shall be confirmed:

(i) minimum shank tension has been obtained; and

(ii) appropriate hardened washers have been fitted in accordance with the requirements of BS 6404.

Table 22.2: Bedding Torque For HSFG Bolts

<table>
<thead>
<tr>
<th>Nominal diameter of bolt</th>
<th>Bedding torque (N.m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>16</td>
<td>80</td>
</tr>
<tr>
<td>20</td>
<td>160</td>
</tr>
<tr>
<td>22</td>
<td>210</td>
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<tr>
<td>24</td>
<td>270</td>
</tr>
<tr>
<td>27</td>
<td>340</td>
</tr>
<tr>
<td>30</td>
<td>460</td>
</tr>
</tbody>
</table>

22.5.10 Movement Connections

(a) Where slotted holes are provided for movement connections, the joints shall be free to move.

(b) Bolted movement connections shall be formed as follows:

(i) the slotted hole shall be wider than the unslotted hole;

(ii) shouldered bolt shall be used with a spring washer under the head and shoulder bearing on the faying surface of the unslotted member; and

(iii) a flat washer shall be provided under the nut and the nut tightened into the unslotted member.

22.5.11 Defects in Steelwork

Defective components for steelwork shall not be used in the Permanent Works unless repair of the defects is permitted by the Project Manager. If permitted, defective components shall be repaired by methods reviewed without objection by the Project Manager.

22.5.12 Cleaning of Steelwork and Coated Surfaces

(a) Soil, concrete and other adherent matter shall be removed immediately from steelwork or coated surfaces and the surfaces shall be made good by methods reviewed without objection by the Project Manager.

(b) Dust, soot, grit, detritus, metallic or other loose particles shall be removed by vacuum cleaning after steelwork surfaces have been blast cleaned or before coated surfaces are washed or steam cleaned.
(c) Oil and grease shall be removed by emulsion cleaners, by steam cleaning or by high pressure water jets before removing rust and mill scale or overcoating. Oil and grease shall not be removed by turpentine or other solvents. If steam cleaning is used, steam cleaning shall be carried out after the greasy deposits have been removed by scraping and a detergent shall be added to the feed water of the steam generator.

(d) Salts, chemicals, corrosion or paint degradation products, including zinc salts on zinc coatings or zinc-rich paints, shall be removed by washing with detergent solution and rinsed with fresh water before coating steelwork surfaces or overcoating.

(e) Rust spotting on blast cleaned surfaces shall be rejected and steel shall be re-blasted to the required standard before any coating is applied.

(f) Residual salts resulting in measurements higher than 90 ppm shall be removed by high pressure fresh water washing.

(g) The final shop coats on external surfaces shall be thoroughly washed with a detergent solution at Site before being overcoated.

(h) Finished coated surfaces shall be cleaned as stated in Sections 22.5.4(b) to (d) not more than 14 days before application for the Completion Certificate for the Works.

(i) Cleaning agents to be used shall be reviewed without objection by the Project Manager. Surfaces which have been cleaned using cleaning agents shall be rinsed with water to remove all traces of the cleaning agent.

(j) Cleaning tools shall not damage the surfaces being cleaned. Wire brushes and brooms shall not be used for cleaning coated surfaces.

22.5.13 Preparation of Steelwork Surfaces

(a) Bare metal surfaces of steelwork which are to be painted or metal coated shall be treated before rust and mill scale are removed in accordance with the following requirements:

(i) burrs, arrises and serrations shall be smoothed by grinding or filing. All surface irregularities shall be removed, including sharp edges and laminations, by grinding until smooth; and

(ii) weld spatter, weld slag and raised metal laminations shall be removed by grinding or chipping and the surface shall be made good.

(b) At no time shall steel surfaces have rusted beyond Rust Grade C of Swedish Standard S1S 05 59 00.

(c) Rust and mill scale shall be removed from steelwork which is to be metal coated in factories by a pickling process compatible with the metal coating process.

(d) Rust and mill scale shall be removed from steelwork which is to be metal sprayed by blast cleaning carried out in accordance with BS 2569:Part 1, Clause 3.

(e) Rust and mill scale shall be removed from steelwork to be painted by blast cleaning as stated in Section 22.5.14 unless the use of acid-pickling, mechanical cleaning or flame cleaning as stated in Sections 22.5.15 to 22.5.17 has been reviewed without objection by the Project Manager.
(f) Excess acid or other chemicals used in the pickling process shall be removed from steelwork which has been prepared by pickling before the application of the metal coating. Pickling shall not be carried out for longer than is necessary to remove the rust and mill scale.

(g) After surface preparation has been completed, the surface roughness shall be compatible with the specified coating and at no location should the peak-to-trough amplitude exceed 80 μm.

(h) All defects in the substrate surface exposed during surface preparation which are not acceptable in accordance with BS 4360 shall be rectified in accordance with BS 4360.

(i) Defects which are acceptable in accordance with BS 4360 but which will prevent the satisfactory coating of the steelwork shall be rectified and reviewed without objection by the Project Manager.

(j) Steelwork which has rusted to Rust Grade B of Swedish Standard SIS 05 59 00 at any stage before surface preparation, and steel which has been subject to significant contamination prior to blast-cleaning, shall be tested in accordance with Appendix G of BS 5493 after surface preparation, to demonstrate that the prepared surface is substantially free of salts.

(k) Prefabrication coatings may be applied but this coating will be considered additional to the main protective-system. If a prefabrication coating is to be applied the Contractor shall provide evidence that it is fully compatible with the main protective system.

22.5.14 Blast Cleaning of Steelwork

(a) Blast cleaning of steelwork shall be carried out to second quality of surface finish in accordance with Sa2½ in Swedish Standard SIS 05 59 00 using chilled iron abrasive.

(b) Chilled iron grit shall be graded in accordance with BS 2451. The maximum size of grit shall be G17 for use in automatic impeller type equipment and shall be G12 for manual or compressed air equipment. The difference in level between a peak and the adjacent trough of the blasted surface profile shall not exceed 0.1 mm or in accordance with the paint manufacturer's recommendation.

(c) All compressed air for grit blasting shall be passed through aftercoolers and oil separation equipment to ensure that the air is dry and oil free. Air shall be tested each day by placing a white cloth at the compressed air outlet for one minute. The cloth shall remain clean after one minute.

(d) Abrasives shall not contain materials which may contaminate the steel surfaces and shall be cleaned and free of chloride, dust, dirt, grease, oil and moisture. Sand shall not be used except in a wet cleaning system. Expandable abrasive shall be used once only. Recyclable steel abrasive shall be cleaned and free of contaminants before re-use. Recyclable abrasives shall be discarded when the particle size fails to achieve the specified profile.

(e) Blast cleaning shall be carried out in a fully enclosed environmentally controlled space separated from the place of painting. The enclosed space shall be fitted with dust extractors and filters to prevent the dispersal of dust outside the enclosed space.
22.5.15 Acid-pickling of Steelwork

Acid-pickling of steelwork shall be carried out by the Footner process in accordance with BS 5493, Clause 14.3.2. The first priming coat of paint shall be applied as soon as the steel has dried and is still warm.

22.5.16 Mechanical Cleaning of Steelwork

Mechanical cleaning of steelwork shall be carried out using carborundum grinding discs or other power-driven tools followed by steel wire brushing and dusting to remove all loosened material which is not firmly bonded to the metal surface. Excessive burnishing of the metal through prolonged application of rotary wire brushes shall not be carried out. Visible peaks and ridges shall be removed. Pneumatic chipping hammers shall not be used.

22.5.17 Flame Cleaning of Steelwork

(a) Flame cleaning of steelwork shall not be carried out at the following locations:

(i) within 2 m of HSFG bolts, cold worked high tensile steel and surfaces already coated with paint or cadmium, lead-based or carbonaceous materials, or

(ii) on sections thinner than 0.5 mm.

(b) Flame cleaning shall be carried out without distorting the steelwork and without adversely affecting the properties of the steel. The temperature of the steel surface being flame cleaned shall not exceed 200°C.

(c) Loose materials shall be removed from the flame-cleaned surface by wire brushing followed by blowing dry air or vacuum cleaning. The priming coat shall be applied when the surface temperature of the steel is between 35°C and 40°C. Surfaces with temperatures of less than 35°C shall be reheated.

22.5.18 Cleaning of Bolts, Nuts and Washers

Bolts, nuts and washers for steelwork shall be kept free from dirt and deleterious material. Oil and grease on bolts, nuts and washers, other than lubricants reviewed without objection by the Project Manager for nuts of HSFG bolts, shall be removed before assembling and coating the exposed parts of assembled bolts, nuts and washers.

22.5.19 Inspection of Surface Preparation

Surfaces shall not be coated until the cleaning and preparation of the surfaces has been carried out. The Contractor shall notify the Project Manager when the surfaces are available for inspection.

22.5.20 Application of Paint to Steelwork

(a) Surfaces which are to be painted shall be dry immediately before paint is applied.

(b) Paint shall be taken from the paint store ready for application. Thinning, if necessary, shall be carried out in the paint store using the type of thinner in the ratio stated in the manufacturer's data sheets.

(c) Paint shall be applied by brush, by air pressure spray or by airless spray. Sealer and primers shall be applied by continuous spraying.
(d) Each coat in the paintwork system shall be sufficiently dry or cured before the next coat is applied. The time between application of successive coats shall be within the limits recommended by the manufacturer and the limits stated in Section 22.5.22.

(e) Paints having a pot life specified by the manufacturer, including two pack paints and moisture cured paints, shall be discarded on expiry of the pot life or at the end of each working day, whichever comes first. Other paints in opened containers shall be kept in sealed containers with not more than 10% ullage in store after each day's work and shall not be thinned or mixed with fresh paint when re-issued for another day's work.

(f) All connections, including fasteners, items of bracketry and other small pieces fabricated separately to the main steelwork shall be prepared and protected using an equivalent standard to the adjacent steel unless otherwise stated in the Contract. If the Contractor proposes to use a different protective system for any part of a connection to that used for the adjacent steel, evidence shall be submitted to the Project Manager which demonstrates compatibility.

(g) Paint shall not be applied to friction grip interfaces. The faying surfaces shall be masked to prevent rusting beyond Rust Grade C of Swedish Standard SIS 05 59 00. If galvanizing or other metal coatings have been applied, evidence shall be provided to demonstrate that a slip factor not less than the design value shall be achieved.

(h) Bolt connections in externally exposed steelwork, other than friction grip connections, shall be assembled with a coat of primer still wet on the contact surfaces.

(i) Plated, galvanized or sherardized bolt assemblies shall be primed with a compatible etch primer or treated with a mordant solution prior to overcoating.

22.5.21 Working Conditions for Painting

(a) Paint shall not be applied to steelwork under the following conditions:
   (i) when the ambient temperature falls below 4°C or the relative humidity rises above 90%;
   (ii) for outdoor work, during periods of inclement weather including fog, frost, mist and rain or when condensation has occurred or is likely to occur on the metal;
   (iii) when the surface temperature of the metal to be painted is less than 3°C above the dew point of the ambient air; or
   (iv) when the amount of dust in the air or on the surface to be painted is in the opinion of the Project Manager excessive.

(b) Two pack paints of the epoxide resin type shall not be applied and cured when the temperature is below that recommended by the manufacturer.

22.5.22 Priming and Overcoating Time Limits

(a) Blast cleaned steel shall be primed or metal coated within 4 hours after blast cleaning and before any visible signs of oxidations appear on the prepared surface. Prepared surfaces shall be blown clean with dry, oil free compressed air to remove dust, dirt and grit residues before coating.

(b) Primed steel surfaces shall be overcoated within 8 weeks after priming.
22.5.23 **Stripe Coats to Steelwork**

Immediately after the first undercoat of the painting system to steelwork has dried, a stripe coat of undercoat paint shall be applied by brush to edges, corners, crevices, exposed parts of bolts, nuts, rivets and welds. Another stripe coat of finishing paint shall be applied in the same manner after the last undercoat has dried.

22.5.24 **Paint Coats to Steelwork**

(a) The dry film thickness of the paint coats to steelwork shall be measured using a magnetic dry film thickness gauge. The total dry film thickness shall be measured at spacings of approximately 1.0 m. If the measured dry film thickness is less than 75% of the specified nominal dry film thicknesses or if more than 10% of the measured dry film thickness are less than 95% of the specified nominal dry film thickness, repair work shall be carried out as stated in Clause 22.5.26.

(b) Dry film thickness readings on structural members shall be taken at three points for each linear metre. Wet film thickness gauges shall not be used as a means of predicting the dry film thickness, but only as an indication that sufficient material has been applied at the time of application.

(c) Each coat of paint shall be free from embedded foreign matter, mechanical damage and surface defects, including bittiness, blistering, brush marks, bubbling, cissing, cracking, cratering, dry spray, floating, pinholing, rivelling, runs, sagging, spotting and spray mottle as defined in BS 2015. The finished paintwork system shall have an even and uniform appearance.

(d) Each coat of paint shall adhere firmly to the substrate without blistering, chipping, flaking or peeling. Adhesion tests in accordance with BS 3900:Part E6 shall be carried out on representative areas to confirm that the adhesion of the completed paint scheme is equivalent to classification 2 of that standard. The test area shall be repaired in accordance with the Specification.
22.5.25 Etch Primers and Blast Primers

Etch primers and blast primers shall not be applied on phosphated steel and shall not be overcoated with zinc-rich primers.

22.5.26 Repairs to Damaged Areas of Paint

(a) Areas of paint to steelwork which have been damaged shall be cleaned to bare metal or to the metal coating. The edges of the undamaged paint shall be bevelled.

(b) The full specified painting system shall be restored in such a manner that each new paint coat overlaps the existing paint by at least 50 mm all round the affected part.

22.5.27 Protection of HSFG Bolted Joints

(a) The faying surfaces of HSFG bolted joints in steelwork which is metal sprayed overall and sealed or metal sprayed and painted overall, shall be coated with the sprayed metal. The sealer on the parent material shall extend for a distance of between 10 mm and 20 mm inside the perimeter of the faying surfaces. Free surfaces and edges of the joint material shall be coated with the same sealer.

(b) The joint material and the faying surfaces on the parent material of steelwork which is metal sprayed only at joints and painted overall shall be metal sprayed. The sprayed metal on the parent material shall extend for a distance of between 10 mm and 20 mm outside the perimeter of the faying surfaces. The primer on the parent material shall extend for a distance of between 10 mm and 20 mm inside the perimeter of the faying surfaces. Sprayed metal on the free surfaces and edges of the joint material shall be coated with a sealer which is compatible with the painting system.

(c) The primer on the parent material of steelwork which is painted overall and uncoated at faying surfaces of HSFG bolted joints shall extend for a distance of between 10 mm and 20 mm inside the perimeter of the faying surfaces.

22.5.28 Protection of other Shop-bolted Joints

Blast primer for painted steelwork or sprayed metal plus sealer for metal sprayed steelwork shall be applied to the joint and parent material of shop-bolted joints other than HSFG bolted joints; joints for painted steelwork shall be assembled after the first undercoat of the painting system has been applied to the contact surfaces and while the undercoat is still wet.

22.5.29 Protection of other Site-bolted joints

Surfaces of the parent and joint material of Site-bolted joints other than HSFG bolted joints shall be coated with the same protective system as the parent material.

22.5.30 Protection of Welded Joints

Welds and steelwork surfaces which have been affected by welding shall be coated with the same protective system as the parent material.
22.5.31  Joints made after Coating the Parent Material

(a) Hot-dip galvanizing and electroplating to steelwork shall not be carried out until all
welds for the steelwork which is to be galvanized or electroplated have been
completed.

(b) Except as stated in Section 22.5.31(d), sprayed metal on the parent material shall be
kept at least 15 mm, but not more than 300 mm, clear of areas which are to be welded. The
restricted area shall be masked during metal spraying.

(c) Except as stated in Section 22.5.31(d), successive coats of paint on the parent material
shall be stepped back at 30 mm intervals commencing at 100 mm from welded joints
and at 10 mm from the perimeter of HSFG bolted joints.

(d) If the parent metal in the welding procedure reviewed without objection by the Project
Manager is coated with the pre-fabrication primer or sprayed metal such coatings are
permitted to cover the area to be welded. After welding the pre-fabrication primer or
sprayed metal adjacent to the weld shall be made good.

(e) The parent material, joint material, exposed parts of bolts, nuts and washers, welds
and weld affected areas shall be cleaned, prepared and brought up to the same
protective system as the adjoining surfaces not more than 14 days after the joints have
been made.

22.5.32  Sealing of Joints in Steelwork

(a) The different parts of joints in steelwork shall be dry immediately before the joints are
assembled.

(b) Gaps around the perimeter of bolted joints and load indicator gaps of HSFG bolts in
steelwork painted overall shall be sealed by brush application of the same painting
system as the parent material; gaps shall be plugged if necessary with soft solder wire
without flux core as a backing before sealing with paint.

22.5.33  Protection of Hollow Steel Sections

The ends of hollow steel sections shall be sealed by welding mild steel plates, at least 2mm
thick, over the open ends. Immediately before hollow steel sections are sealed, porous bags
containing anhydrous silica gel shall be inserted in each void at the rate of 0.25 kg/m³ of
void.

22.5.34  Protection of Bearing Surfaces for Bridge Bearings

Dirt, oil, grease, rust and mill scale shall be removed from the metal bearing surfaces for
bridge bearings. The surfaces shall be masked with tape and shall not be primed or painted
until the bonding agent has been applied.

22.5.35  Protection of Uncoated Steelwork Surfaces

The coated surfaces of steelwork coated over part of the surface shall be protected from rust
which may form on the uncoated surfaces. Temporary coatings which may affect the bond
between concrete and uncoated surfaces against which the concrete is to be placed shall be
removed and the uncoated surfaces shall be cleaned before the concrete is placed. The full
coating system shall extend 25 mm, or 75 mm for steel piles, into areas against which
concrete is to be placed.
22.5.36 Temporary Supports and Fastenings to Steelwork

(a) Steelwork shall be secured in position by temporary supports and fastenings until sufficient permanent connections are complete to withstand the loadings liable to be encountered during erection. The temporary supports and fastenings shall be capable of withstanding loadings which may be encountered during erection and shall not damage the steelwork or the protective coatings.

(b) Riveted and bolted connections shall be aligned using drifts complying with BS 5400:Part 6, Clause 4.12 and shall be temporarily fastened using service bolts.

(c) The Contractor shall design and fabricate all temporary attachments for use as assembly and erection aids to ensure their use will not damage the structure of its surface protection.

22.5.37 Falsework

Falsework shall be designed, constructed and dismantled in accordance with BS 5975.

22.5.38 Alignment of Steelwork

(a) Steelwork shall be erected in such a manner that the alignment and levels of the steelwork comply with the tolerances stated in Section 22.5.49. The Contractor shall make allowance for the effects of temperature on the steelwork.

(b) Measures shall be taken to ensure that the steelwork will remain stable before temporary supports and fastenings are slackened or removed for lining, levelling, plumbing or other purposes. The temporary supports and fastenings shall be re-tightened or replaced as soon as the adjustments are complete and at the end of each continuous period of working.

(c) Permanent connections shall be made as soon as a sufficient portion of the steelwork has been lined, levelled and plumbed. Temporary supports and fastenings shall be replaced by permanent connections progressively and in such a manner that the parts connected are securely restrained in the aligned position at all times.

22.5.39 Foundation Bolts for Steelwork

(a) Foundation bolts for steelwork shall be held firmly in the set position during fixing. Measures shall be taken to ensure that the full movement tolerances are achieved and the bolts are not displaced during concreting. Bolts and nuts, including the threads, shall be protected against damage, corrosion and contamination.

(b) Bolt pockets shall be kept dry and clean. Tubes which are cast in concrete for grouting bolt pockets shall be securely fixed and sealed to prevent ingress of grout during concreting.

(c) Bolts in bolt pockets shall be installed to allow the bolt movement inside the pocket as designed without hindrance.

22.5.40 Supporting Devices for Steelwork

The material, size, position and cover of packs, shims and other supporting devices for steelwork which are to be embedded shall be as reviewed without objection by the Project Manager.
22.5.41 Bedding and Grouting of Column Bases

(a) Column bases for each portion of steelwork shall not be bedded or grouted until the portion has been lined, levelled, plumbed and permanently connected. Spaces below the steel shall be dry, clean and free from rust immediately before bedding or grouting.

(b) Proprietary types of grout shall be used in accordance with the manufacturer's recommendations.

(c) Temporary timber wedges holding steel columns in position shall not project into pocket bases by more than one-third of the embedded length of the steel column. The pocket shall be initially concreted up to the underside of the wedges and the steel column shall be left undisturbed until 48 hours after concreting; the wedges shall then be removed and the remainder of the pocket shall be concreted.

22.5.42 Sliding Surfaces

Sliding surfaces of uncoated expansion joints shall be treated with molybdenum disulphide grease before making the connection.

22.5.43 Thermal Cutting

Thermal cutting equipment shall not be used on Site unless reviewed without objection by the Project Manager.

22.5.44 Erectors

The Contractor shall carry out all work by trained and experienced erectors. The Contractor shall submit to the Project Manager for review evidence of the erector’s competence.

22.5.45 Safety

The Contractor shall not carry out complex operations at height except from safe platforms large enough to support operators and equipments. Platforms and safe access shall be maintained until work has been completed.

22.5.46 Stability

Stability of structures shall be checked by calculations submitted to the Project Manager for review. The design criteria assumed in the calculations shall be maintained at all stages of construction.

22.5.47 Tolerances: Fabrication of Steelwork

(a) Unless otherwise stated in the Contract, steelwork shall be fabricated to within the tolerances stated in Sections 22.5.47(b) to (i).

(b) Steelwork shall be fabricated to an accuracy that will enable erection within the specified limits to take place without inducing excessive stresses, deflection or distortion into the structure.

(c) Built-up members, including castellated beams shall comply with BS 5950:Part 2.

(d) The length of members with both ends prepared for contact bearing shall not deviate from the detailed length by more than 1 mm.
(e) The length of members without ends prepared for contact bearing, which are to be framed to other steel parts of the structure, shall not deviate from the detailed length by more than 2 mm for members 10 m or less in length, and 4 mm for members greater than 10 m in length.

(f) The deviation of a member from a straight line drawn between adjacent points of subsequent effective lateral restraint shall not exceed the greater of 3 mm or 0.1% of the distance between restraints.

(g) The deviation from the specified or proposed camber shall not exceed the greater of 12 mm or 0.1% of the length of the member.

(h) The gaps in joints which depend on contact bearing when assembled during fabrication shall not exceed 0.75 mm.

(i) Fabrication tolerances shall comply with the following British Standards:

   (i) BS 5400:Part 6 for plates and sections in bridgework;

   (ii) BS 5950:Part 2 for hot rolled sections in building; and

   (iii) BS 5950:Part 7 for cold rolled sections in building.

22.5.48 Tolerances: Foundation Bolts

The position of cast-in foundation bolts at the top of base plates shall be within 3 mm of the specified position. The position of foundation bolts in bolt pockets at the top of base plates shall be within 5 mm of the specified position. The line of bolts shall not be tilted from the specified line by more than 1 in 40.

22.5.49 Tolerances: Erection of Steelwork

(a) Unless otherwise stated in the Contract, steelwork shall be erected to within the tolerances stated in Sections 22.5.49(b) to (j) after lining, levelling, plumbing and making the permanent connections.

(b) The position in plan of vertical components at the base shall be within 10 mm of the specified position along either principle setting out axis.

(c) The level of the top of base plates and the level of the lower end of vertical or raking components in a pocket base shall be within 10 mm of the specified level.

(d) The thickness of bedding shall be within one-third of the nominal thickness or 10 mm, whichever is less, of the specified nominal thickness.

(e) The line of vertical or raking components other than in portal frames shall be within 1 in 600 and within 5 mm of the specified line in every direction.

(f) The line of vertical or raking components in portal frames shall be within 1 in 600 and within 5 mm of the specified line in every direction.

(g) The position and level of components connected with other components shall be within 5 mm of the specified position and level relative to the other components at the point of connection.
(h) The position of components supported on a bearing shall be within 5 mm of the specified position relative to the bearing along both principal axis of the bearing.

(i) The difference in level between adjacent sloping or horizontal components connected by a deck slab shall be within 10 mm of the specified difference in level.

(j) Gaps in joints which depend on contact bearing after alignment shall not exceed 0.75 mm.

22.6 INSPECTION TESTING AND COMMISSIONING

22.6.1 Procedure Trials for Welding, Flame Cutting and Shearing

(a) If the proposed welding procedure submitted as stated in Section 22.4.5 or the proposed stud welding, flame cutting or shearing procedure for steelwork complying with BS 5400:Part 6 submitted as stated in Section 22.4.6 has not complied with the procedure trial requirements for the procedure stated in the Contract in previous tests, a procedure trial shall be carried out as stated in Sections 22.6.1 (b) to (h).

(b) Procedure trials for welding for structural steel shall comply with BS 5400:Part 6, Clauses 4.7.3, 5.4.1.1 and 5.4.1.2.

(c) Procedure trials for welding for steel castings shall comply with BS 5400:Part 6, Clauses 4.7.3 and 5.4.2.

(d) Procedure trials for welding of studs shall comply with BS 5400:Part 6, Clauses 4.7.4 and 5.4.4.

(e) Procedure trials for flame cutting and shearing shall comply with BS 5400:Part 6, Clauses 4.7.3 and 5.4.3.

(f) Welds for grade A steels complying with BS 4360 are not required to comply with the requirements for Charpy V-notch impact tests. The temperature of -20°C stated in BS 5400:Part 6, Clause 5.4.1.2(a)(3) shall be amended to 0°C.

(g) If in a welding procedure one or more of the parts to be welded is coated with a prefabrication primer or metal coating before welding, the same primer or coating shall be applied to the sample before the procedure trial for the welding procedure is carried out.

(h) The thickness of the sample of material to be used in procedure trials for flame cutting shall be:

(i) 20 mm for material not exceeding 20 mm thick;

(ii) 40 mm for material exceeding 20 mm and not exceeding 40 mm thick; and

(iii) T mm for material exceeding (T-10) mm and not exceeding T mm thick, where T is any multiple of 10 from 50 up.

22.6.2 Inspection of Procedure Trials for Welding, Flame Cutting and Shearing

Procedure trials for welding, flame cutting and shearing shall be carried out in the presence of an independent HOKLAS accredited inspecting authority.
22.6.3 Results of Procedure Trials for Welding, Flame Cutting and Shearing

If a procedure trial for welding, flame cutting or shearing does not comply with the specified requirements for the procedure trial, the cause of failure shall be established by the Contractor and particulars of proposed changes shall be submitted to the Project Manager for review. Further procedure trials shall be carried out to establish the amended procedure.

22.6.4 Acceptable Procedures for Welding, Flame Cutting and shearing

(a) A welding, flame cutting or shearing procedure which complies with the specified requirements for the procedure trial is defined as an "Acceptable Procedure".

(b) If a procedure trial is not required, the procedure for welding, flame cutting or shearing submitted as stated in Sections 22.4.5 and 22.4.6 shall become an "Acceptable Procedure".

22.6.5 Commencement of Welding, Flame Cutting and Shearing

Welding, flame cutting or shearing shall not commence until the procedure has been reviewed without objection by the Project Manager.

22.6.6 Changes in Procedures for Welding, Flame Cutting and Shearing

"Acceptable Procedures" for welding, flame cutting or shearing shall not be changed. Further procedure trials shall be carried out to demonstrate proposed changes to the procedure.

22.6.7 Records of Procedure Trials for Welding, Flame Cutting and Shearing

(a) A record of the approval test for welding procedures shall be submitted to the Project Manager for review. The record shall be in the form stated in BS 4870:Part 1, Appendix B or BS 4570, Appendix A as appropriate and shall be endorsed by the independent HOKLAS accredited inspecting authority.

(b) Reports of procedure trials for stud welding, flame cutting and shearing shall be submitted to the Project Manager for review.

22.6.8 Painting Trials

(a) A painting trial shall be carried out for each painting system which will be applied to areas exceeding 10 m² to demonstrate that the proposed materials and methods of application will produce a painted surface which complies with the specified requirements.

(b) Painting trials shall be carried out at the place where painting to the Permanent Works will be carried out and using the labour and equipment which will be used to carry out painting to the Permanent Works.

(c) Painting trials shall be carried out on steel cleaned in accordance with the requirements of the Contract.
22.6.9  Results of Painting Trials

The painted surface produced in a painting trial shall be tested in accordance with BS 3900 and in the event that the test piece does not comply with the specified requirements for the paintwork, the cause of failure shall be established by the Contractor and particulars of proposed changes shall be submitted to the Project Manager for review. Proposed changes to the paint formulation, other than an adjustment in the amount of thinners, shall be carried out at the paint manufacturer's works before the final painting trial and before the first batch of paint is delivered.

22.6.10  Commencement of Painting

Painting shall not commence until the painted surface produced in painting trials complies with the specified requirements for paintwork.

22.6.11  Changes in Materials and Methods of Application for Painting

The materials and methods of application used in a painting trial which complies with the specified requirements shall not be changed.

22.6.12  Inspection of Fabricated Steelwork

(a) Fabricated steelwork shall not be:

   (i) covered with protective coatings, concrete or other materials;
   
   (ii) erected; or

   (iii) dispatched from the place of fabrication if fabricated off site,

   until the steelwork, complies with the specified test and inspection requirements and has been reviewed without objection by the Project Manager.

22.6.13  Independent Testing Consultant

Tests which are stated in this section to be carried out by an independent testing consultant shall be carried out by a HOKLAS accredited testing consultant reviewed without objection by the Project Manager.

22.6.14  Testing: Tests on Steelwork at Manufacturer's Works

(a) Tests shall be carried out on structural steel in accordance with BS 5400:Part 6, Clauses 5.2.1, 5.2.2 and 5.3.

(b) Tests shall be carried out on bolts, nuts and washers in accordance with BS 3692, BS 4190, BS 4395:Part 1, BS 4395:Part 2, BS 4395:Part 3 or BS 4933 as appropriate; the tests shall be carried out on full size bolts. The rates of sampling and testing shall be in accordance with BS 4395:Part 1.

(c) The tests shall be carried out by the manufacturer at the manufacturer's works on samples selected by the Project Manager if the manufacturer's works are in Hong Kong and on samples selected by the independent testing consultant reviewed without objection by the Project Manager if the manufacturer's works are not in Hong Kong.
22.6.15 Batch: Steelwork

(a) A batch of steelwork is the amount of steelwork which is completed or delivered to Site at any one time.

(b) The Contractor shall submit to the Project Manager for review a list of the components included in each batch at least 7 days before testing starts.

22.6.16 Samples: Steelwork

(a) Samples to be tested shall be selected by the Project Manager if testing is to be carried out in Hong Kong and shall be selected by the independent testing consultant if testing is not to be carried out in Hong Kong.

(b) Samples shall be selected from positions which, in the opinion of the Project Manager or the independent testing consultant, are representative of the batch as a whole.

(c) The Project Manager will inform the Contractor of the samples selected for testing at least 3 days before testing is programmed to commence.

22.6.17 Testing: Steelwork

(a) The relevant tests stated in Sections 22.6.21 to 22.6.24 shall be carried out on each batch of steelwork.

(b) The Contractor shall notify the Project Manager at least 7 days before tests in Hong Kong are carried out.

22.6.18 Reports of Tests on Steelwork

(a) Records of tests on steelwork and a report shall be submitted to the Project Manager for review at least 7 days before the Project Manager's notification of no objection is required. The report shall contain the following details:

(i) procedure under which the testing took place and the exact test location in the steelwork;

(ii) results of tests compared to the required values, with any non-complying results highlighted;

(iii) any tearing, cracking or other defects; and

(iv) conclusion as to the overall acceptability of the parts of steelwork examined by the testing consultant.

(b) Reports shall be certified by the Contractor and by the independent testing consultant, who carried out the tests.

22.6.19 Non-compliance: Steelwork

(a) If the result of any test on steelwork stated in Sections 22.6.21 to 22.6.24 does not comply with the Specification for the test, the test shall be carried out on additional samples from the batch. The number of additional tests shall be twice the number of original tests.
(b) If the result of every additional test complies with the Specification, the part of the batch on which the original tests were carried out shall be considered as complying with the specified requirements for the test.

(c) The batch shall be considered as not complying with the Specification if the result of any additional test does not comply with the Specification for the test.

22.6.20 Samples: Steel

Samples of steel shall be provided from each batch of steel within 3 days after delivery of the batch to the fabricator's works or to Site. The rate of sampling and the position and direction of the samples shall be in accordance with BS 4360.

22.6.21 Testing: Steel

(a) The tensile test and the impact test shall be carried out on each sample of steel. The method of testing shall be in accordance with BS 4360.

(b) Where stated in the Contract the material shall be subject to the following additional tests:
   (i) ultrasonic grading in accordance with BS 5996, Grade 4; and
   (ii) through thickness tensile tests to BS 6780, Level Z25.

(c) Quality grading of structural steel shall be carried out on steel which has not been tested for quality grades by the manufacturer. Quality grading shall be carried out in accordance with BS 5400:Part 6, Clause 3.1.4 or BS 5950:Part 2, Clause 2.1.6 as appropriate.

(d) Testing and quality grading shall be carried out by the independent testing consultant.

22.6.22 Testing: Welds

(a) Examination and testing of welds shall be carried out after post-weld heat treatment and before the application of corrosion protective coatings. De-burring, dressing, grinding, machining and peening shall be carried out after the visual inspection for cracks, surface pores and joint fit-up and before other inspections and tests are carried out.

(b) Where the Specification requires that butt welds are subject to non-destructive examination, the following shall apply:
   (i) visual inspection in accordance with BS 5289;
   (ii) penetrant test in accordance with BS 6443 or magnetic particle test in accordance with BS 6072;
   (iii) ultrasonic examination to BS 3923: Part 1, Part 2; and
   (iv) radiographic examination to BS 2600:Part 1, Part 2 or BS 2910.
(c) Where the Specification requires that fillet welds are subject to the non-destructive examinations, the following shall apply:

(i) visual inspection in accordance with BS 5289;

(ii) penetrant test in accordance with BS 6443 or magnetic particle test in accordance with BS 6072; and

(iii) for welds with a leg length equal to or greater than 12 mm ultrasonic examination to BS 3923:Part 1.

(d) Welds subject to visual examination shall satisfy the following criteria:

(i) no evidence of cracks, spattering, inclusions, tears or lack of fusion;

(ii) weld sizes and lengths shall not be less than those dimensions specified in the Specification;

(iii) any undercut shall be intermittent and not greater than 0.5 mm deep;

(iv) full penetration shall be achieved unless otherwise specified in the Contract. For connections welded from one side only, any lack of penetration shall be intermittent and not greater than 1.5 mm deep;

(v) root gap in fillet welds shall not exceed 1.0 mm and shall only exceed 0.5 mm intermittently;

(vi) excess penetration shall not exceed 3 mm;

(vii) weld reinforcement shall blend smoothly with the parent metal with no signs of overlap; and

(viii) linear misalignment shall not exceed t/10 where t is the thickness of the thinner part or 3 mm, whichever is the lesser.

(e) Welds subject to ultrasonic examination shall satisfy the following criteria:

(i) the weld shall have no reflectors which could be interpreted as planar defects such as cracks, tears, lack of fusion or lack of penetration. A planar defect is any flaw whose thickness is less than 25% of its width. In the case of partial penetration welds, the nominated unfused thickness shall not be subject to rejection. The amount of unfused thickness shall be measured and recorded and shall not exceed the nominated width;

(ii) all volumetric defects, where the thickness is equal to or greater than 25% of its width, shall be sized and the weld rejected if:

- the width exceeds 6 mm or T/6, whichever is the lesser; or
- where the width exceeds 1.5 mm, but is less than 6 mm or T/6 whichever is lesser, the length exceeds 20 mm (T equals the plate thickness in mm);

(iii) two adjacent defects, if not separated by at least twice the length of the longer defect, shall be regarded as one continuous defect; and

(iv) a defect shall not begin at a distance less than twice its own length from the end of the weld.
(f) Welds subject to magnetic particle or penetrant examination shall satisfy the following criteria:

(i) the weld shall have no cracks, tears, or lack of fusion;

(ii) any undercut shall be intermittent and not greater than 0.5 mm deep;

(iii) the sum of diameters of piping or porosity shall not exceed 10 mm in any linear 25 mm of weld and 20 mm in any 300 mm length of weld;

(iv) maximum length of a single defect shall be less than 2/3 of the effective throat of the weld up to a maximum of 20 mm;

(v) the defect shall be further than three times the larger of its own width or length from the end of the weld or from an adjacent defect;

(vi) any indication which is believed to be spurious shall be regarded as a defect unless on re-evaluation by the same method or by an alternative technique subsequent to surface dressing the indication has been removed; and

(vii) any defects which appear to be subsurface shall be exposed by surface grinding to display their nature, full size, and shape.

(g) The frequency of weld examination shall be in accordance with requirements in PNAP 160 or the following, whichever is the greater.

(i) all welds shall be visually inspected; and

(ii) for non-destructive examination the frequency shall be as follows:

- full penetration butt welds:
  
  • 100% ultrasonic; and
  
  • 100% magnetic particle or penetrant inspection;

- partial penetration butt welds and fillet welds with leg length equal to or greater than 12 mm:
  
  • 20% minimum ultrasonic; and
  
  • 20% minimum magnetic particle or penetrant inspection; and

- Fillet welds with leg length less than 12 mm:
  
  • 10% minimum magnetic particle or penetrant inspection.

(h) Testing of stud welding shall be as follows:

(i) all stud welds shall be visually inspected;

(ii) any stud weld which does not exhibit full 360 degree "flash" shall be subjected to a 15 degree bend test at locations to be reviewed without objection by the Project Manager. Under this test the weld is to show no visible signs of cracking;

(iii) a minimum of 5% of studs which have satisfied the visual inspection shall be subject to a 15 degree bend test at locations to be reviewed without objection by the Project Manager. Under this test the weld shall show no visible signs of cracking;
(iv) where the bend test reveals an unsatisfactory stud weld, an additional stud on each side of the defective stud shall be tested; and

(v) all defective studs shall be replaced and re-tested.

(i) Testing of welds shall be carried out by the independent testing consultant.

(j) Records of weld testing shall be submitted to the Project Manager for review in a form suitable for submission to the Buildings Department.

22.6.23 Testing: Fabrication Tolerances

(a) Rolled and built-up sections of steelwork complying with BS 5400:Part 6 shall be tested to determine compliance with fabrication tolerances in accordance with BS 5400:Part 6, Clauses 5.6.1 to 5.6.6.

22.6.24 Testing: Repairs

Defects which have been repaired and adjoining areas which in the opinion of the Project Manager may have been affected by the repair shall be retested.
SECTION 23 BRIDGEBEARING works

23.1 GENERAL

23.1.1 Movement Joints Formed in Place

Movement joints formed in place shall comply with Section 20 except as stated in this Section.

23.2 DEFINITIONS AND ABBREVIATIONS

23.2.1 Schedule of Bearings

Schedule of bearings is the schedule of bearings stated in the Contract.

23.2.2 Type of Bridge Bearing

“Type of bridge bearing” is a term used to identify bridge bearings of exactly the same design and same capacity for all bearing loads, movements and rotations.

23.2.3 Batch: Bridge Bearings

A batch of bridge bearings is any quantity of bridge bearings of the same type fabricated by the same manufacturer and which for the purpose of testing elastomeric bearings contains the same type of elastomer.

23.2.4 Fabricated Movement Joint

Fabricated movement joint is a manufactured assembly, including nosings, designed to carry traffic smoothly over a movement joint and to seal the joint against the ingress of water and debris.

23.2.5 Movement Joint

Movement joint is a permanent joint or hinge throat which allows expansion, contraction or angular rotation to occur.

23.2.6 Movement Joint Formed in Place

Movement joint formed in place is a movement joint formed during construction of a structure to permit adjacent structural elements to move relative to each other without damage.

23.3 DESIGN AND PERFORMANCE CRITERIA

23.3.1 Design of Bridge Bearings

(a) Bridge bearings shall be designed by the Contractor unless otherwise stated in the Contract.
(b) The design and manufacture of bridge bearings and the materials used shall comply with BS 5400:Part 9, including the guidance notes, except as stated in Clauses 23.3.2 and 23.3.3. Inspection and maintenance of bridge bearings shall be easy to carry out and the bearings shall be easily replaceable.

(c) The maximum bearing stress in concrete underlying or overlying a bridge bearing under the design load at the ultimate limit state shall not exceed 40% of the specified grade strength of the concrete. Higher bearing stresses may be adopted provided that sufficient steel reinforcement is provided to resist the resulting bursting forces and that the bearing stresses are within the limits stated in Clause 7.2.3.3 of BS 5400:Part 4.

(d) The deflection of bridge bearings which have a specified zero horizontal movement in a particular direction shall not exceed 1 mm in that direction under the maximum horizontal loadings

23.3.2 Design of Sliding Bearings

(a) Clause 4.3.4.2 of BS 5400:Part 9:Section 9.2 shall not apply to sliding bearings.

(b) Stainless steel sliding surfaces of sliding bearings which are attached to backing plates by mechanical fasteners instead of continuous welding along the edges shall be bonded to the backing over the full area and supplemented with peripheral sealing if necessary. Mechanical fixing by peripheral sealing only shall not be used.

23.3.3 Design of Elastomeric Bearings

The requirements for use of elastomer in elastomeric bearings at subzero temperatures stated in Clause 3.7.1 of BS 5400:Part 9:Section 9.2 shall not apply.

23.3.4 Design of Guides for Bridge Bearings

The clearance between guides and complementary sliding surfaces of a guided bearing shall not exceed 1 mm.

23.3.5 Design of Fixings for Bridge Bearings

(a) Except for elastomeric bearings, bridge bearings, including bearings which are not required to provide horizontal restraint, shall be fixed to the superstructure and substructure with mechanical fixings or by other methods reviewed without objection by the Project Manager. The Contractor may propose to use friction between the bearing and the superstructure or substructure to resist the horizontal forces provided he shall apply a factor of safety of at least 2 to the proven coefficient of friction and that the worst combination of vertical load and horizontal load is considered.

(b) The ultimate capacity of the mechanical fixings for bridge bearings shall not be less than the worst combination of loading at ultimate limit state stated in the schedule of bearings.

23.3.6 Design of Fabricated Movement Joints

(a) Fabricated movement joints shall be a proprietary type reviewed without objection by the Project Manager.
(b) Fabricated movement joints shall be capable of withstanding the following loads, either separately or in combination:

(i) vertically: two 112.5 kN wheel loads, 1 m apart, each spread over a contact area giving an average pressure of 1 MPa and applied in such a manner as to produce the worst possible effect; and

(ii) horizontally: a traction force of 75 kN/m run of the joint applied perpendicular to the alignment of the joint, together with any forces arising from strain of the joint.

Allowance for additional loading due to impact is not necessary.

(c) Fabricated movement joints shall accommodate the movements and rotations stated in the Specification without damaging the joint and without loading the supporting structure with forces which arise from strain of the joint exceeding 5 kN/m run of the joint.

(d) Fabricated movement joints shall either be watertight or provided with a drainage layer or channel to collect water passing through the joint and to divert the water away from the underlying structure.

(e) Fabricated movement joints shall provide easy clearance of grit or silt entering slots, grooves or channels forming or associated with the joint.

(f) Surfaces of fabricated movement joints which will be exposed at finished road level shall provide a resistance to skidding not less than that of the adjacent road surface.

(g) Fabricated movement joints shall not impair the riding quality of the road surface for vehicular traffic and the passage of vehicular traffic shall not cause undue noise or vibration. The size of gaps, including gaps sealed with flexible material, on the riding surface of the joint shall not exceed 65 mm.

(h) The passage of pedestrians and cyclists shall not be impeded or endangered by fabricated movement joints.

**23.3.7 Design of Fixings for Fabricated Movement Joints**

(a) The holding down and fixing arrangements for fabricated movement joints shall be capable of withstanding the loads stated in Clause 23.3.6(b). The diameter of bolts fixed as double row bolts on one side shall be at least 12 mm and the diameter of other holding down bolts and studs shall be at least 16 mm.

(b) Fixings for fabricated movement joints shall be compatible with the reinforcement in the underlying concrete. Any revisions to the reinforcement required to suit the fixings shall be designed by the Contractor and submitted to the Project Manager for review.
23.4 MATERIALS

23.4.1 Prefabricated Sheeting

(a) Prefabricated sheeting for waterproofing shall be a proprietary type reviewed without objection by the Project Manager.

(b) Prefabricated sheeting shall not rot or support the growth of mildew and shall be compatible with the materials with which it is in contact. Prefabricated sheeting which will be exposed to sunlight after installation shall be of a type unaffected by ultraviolet light.

(c) Prefabricated sheeting shall have a tensile strength, pliability and puncture resistance such that the sheeting will withstand the stresses induced during handling and laying without damage. The elongation properties of prefabricated sheeting shall be such that the sheeting can accommodate the creep, shrinkage and thermal movements of concrete without distress.

(d) Prefabricated bituminous sheeting shall be a self-adhesive, self-sealing type and shall have a thickness of at least 1.2 mm.

(e) Prefabricated rubberised base sheeting shall be of a type which is unaffected by fuels, oils or grease.

(f) Primers and mastic for prefabricated sheeting shall be a proprietary type recommended by the sheeting manufacturer and reviewed without objection by the Project Manager.

23.4.2 Bentonite Panels

(a) Bentonite panels shall consist of bentonite filler enclosed in self-degradable boards. The panels shall have a permeability of less than $1 \times 10^{-7}$ mm/sec under simulated test conditions similar to those of the as-built conditions. The performance of bentonite panels shall not be affected by contaminants present in the groundwater.

(b) Bentonite panels for slabs less than 200 mm thick or with soil cover of less than 450 mm shall be special panels with specific provision for swelling to prevent lifting of the slab.

(c) Bentonite joint seal and bentonite granules shall be a proprietary type recommended by the bentonite panel manufacturer and reviewed without objection by the Project Manager.

(d) Polyethylene sheeting for use with bentonite panels shall be a heavy duty type.

23.4.3 Delivery of Bentonite Panels

Bentonite panels shall be delivered in original unbroken packages bearing the manufacturer's label.
23.4.4 Storage of Materials for Waterproofing Systems

(a) Prefabricated sheeting and bentonite panels shall be stored in accordance with the manufacturers' recommendations in a dry weatherproof store with a raised floor.

(b) Bituminous paint shall be stored in sealed containers marked to identify the contents and protected from exposure to conditions which may affect the bituminous paint. The bituminous paint shall be stored in accordance with the manufacturer's recommendations and shall not be used after the recommended shelf life has been exceeded.

23.4.5 Bituminous Paint

Bituminous paint for waterproofing shall be cut-back bitumen complying with BS 3690:Part 1. The bitumen shall have a viscosity grade as determined by a standard tar viscometer within the range 25 - 50 seconds with a coverage of 0.5 L/m². Primers for bituminous paint shall be a proprietary type recommended by the bituminous paint manufacturer and reviewed without objection by the Project Manager.

23.4.6 Holding Down Bolts for Bridge Bearings

Holding down bolts for bridge bearings shall be a proprietary type reviewed without objection by the Project Manager.

23.4.7 Cement Mortar, Grout and Adhesive for Bridge Bearings

(a) Cement mortar for bedding and construction of unreinforced plinths for bridge bearings shall be a proprietary non-shrink type with a grade strength of at least 50 MPa reviewed without objection by the Project Manager.

(b) Chemical-resin mortar for the construction of plinths for bridge bearings shall be a proprietary non-shrink type with a grade strength of at least 50 MPa reviewed without objection by the Project Manager.

(c) Grout for grouting base plates and holding down bolts shall be a proprietary non-shrink cementitious type with a grade strength of at least 50 MPa reviewed without objection by the Project Manager. The grout shall readily flow under base plates and shall not bleed or segregate. The suitability of the grout shall be demonstrated by Site trials and reviewed without objection by the Project Manager.

(d) Adhesives and chemical resin mortars for locating and bedding elastomeric bridge bearings shall be a proprietary type reviewed without objection by the Project Manager. They shall be compatible with the elastomer.

23.4.8 Dowel Bars for Bridge Bearings

Dowel bars for bridge bearings shall be Grade 316 S 31 or 316 S 33 stainless steel complying with BS 970:Part 1.

23.4.9 Protective Coatings to Bridge Bearings

Metal components of bridge bearings shall be protected against corrosion by a protective coating complying with, and selected in accordance with, BS 5493. For the purpose of selecting the coating system, the environment shall be classified as 'exterior exposed - polluted coastal' and the typical time to first maintenance shall be 'very long' (20 years or more).
23.4.10 Marking of Bridge Bearings

(a) Bridge bearings shall be marked by the manufacturer either with the type numbers stated in the schedule of bearings or with the manufacturer's own type or other numbers. A schedule shall be provided which relates the manufacturer's own type or other numbers to the type numbers stated in the schedule of bearings.

(b) The design movement directions and magnitudes and the axes of bearing shall be marked on the upper faces of bridge bearings to facilitate checking of the installation. Movement indicators shall be provided for sliding and roller bearings to permit checking of movements of the bearings before and after installation.

23.4.11 Vehicular Parapets

(a) Vehicular parapets shall be of the types stated in the Contract.

(b) Steel for vehicular parapets, including welding, shall comply with Section 18 except that the requirements for testing shall not apply.

(c) Protective treatment to steel for vehicular parapets shall comply with Section 18 and shall be applied after welding, drilling and cutting is complete.

(d) Aluminium for vehicular parapets shall comply with the following:

   Wrought aluminium and aluminium alloys for general engineering purposes
   - plate, sheet and strip : BS 1470
   - rivet, bolt and screw stock : BS 1473
   - bars, extruded round tubes and sections : BS 1474.

(e) Aluminium shall be anodised to Grade AA 25 in accordance with BS 1615.

(f) Welding of aluminium for vehicular parapets shall comply with the following:

   (i) TIG welding of aluminium, magnesium and their alloys : BS 3019:Part 1; and

   (ii) Aluminium and aluminium alloys : BS 3571:Part 1

(g) Stainless steel bolts, nuts and washers for vehicular parapets shall be Grade A4-80 and shall comply with BS 6105.

23.4.12 Holding Down Bolts for Vehicular Parapets

Holding down bolts for vehicular parapets shall be a proprietary type reviewed without objection by the Project Manager.

23.4.13 Grout for Vehicular Parapets

Grout for holding down bolts for vehicular parapets shall be based on polyester resins and shall be a proprietary type reviewed without objection by the Project Manager.

23.4.14 Joint Filler

Joint filler for movement joints formed in place shall be non-absorbent.
23.4.15 Joint Sealant

(a) Joint sealant for movement joints formed in place shall be a polysulphide-based sealant. Polyurethane-based sealant shall not be used.

(b) Joint sealant shall be resistant to attack by petrol, diesel oil, dilute acids and alkalis, synthetic and mineral oils, hydraulic fluids and paraffin. The sealant shall have a transverse butt joint movement range for repeated cyclic movement of at least 25% of the width of the joint.

23.4.16 Compression Seals

Compression seals shall be a proprietary type reviewed without objection by the Project Manager and shall be manufactured from natural rubber, neoprene or other synthetic material. Compression seals shall have the dimensions specified by the manufacturer for each joint width.

23.4.17 PVC capping Strip

PVC capping strip shall be a proprietary type reviewed without objection by the Project Manager.

23.4.18 Holding-down Bolts for Movement Joints

Holding-down bolts for movement joints shall be a proprietary type reviewed without objection by the Project Manager.

23.4.19 Grout for Movement Joints

Grout for holding-down bolts for movement joints shall be based on polyester resins and shall be a proprietary type reviewed without objection by the Project Manager.

23.5 SUBMISSIONS

23.5.1 Particulars of Waterproofing Systems

(a) The following particulars of the proposed waterproofing systems shall be submitted to the Project Manager for review:

   (i) manufacturer's literature and a certificate for prefabricated sheeting showing the manufacturer's name, the date and place of manufacture and showing that the prefabricated sheeting complies with the Specification including results of tests for:

      - tensile strength;
      - pliability;
      - puncture resistance; and
      - elongation;

   (ii) manufacturer's literature and a certificate for bentonite panels showing the manufacturer's name, the date and place of manufacture and showing that the bentonite panels comply with the Specification including results of tests for permeability;
(iii) manufacturer's literature and a certificate for bituminous paint showing the manufacturer's name, the date and place of manufacture and showing that the bituminous paint complies with the Specification including results of tests for viscosity;

(iv) particulars of primers and mastic for prefabricated sheeting, bentonite joint seal and bentonite granules and primers for bituminous paint; and

(v) methods of laying prefabricated sheeting and bentonite panels.

23.5.2 Representative Samples of Materials for Waterproofing Systems

(a) Representative samples of the following proposed materials for waterproofing systems shall be submitted to the Project Manager for review:

(i) prefabricated sheeting; and

(ii) bentonite panels.

23.5.3 Particulars of Bridge Bearings

(a) The following particulars of the proposed bridge bearings shall be submitted to the Project Manager for review:

(i) details of type of bridge bearings, including materials, and the name and address of the manufacturer;

(ii) design calculations, including calculations of bearing stresses above and below the bearings and calculations for bursting or other necessary additional or revised reinforcement;

(iii) Contractor’s Drawings of bearings including installation thereof and any additional or revised reinforcement details;

(iv) a certificate for each type of bridge bearing showing the manufacturer's name, the date and place of manufacture and showing that the bridge bearings comply with the Specification including results of:

- friction tests;
- load tests;
- tests on elastomers;
- quick production tests; and
- stiffness tests;

(v) values of stiffness in compression and in shear of elastomeric bearings;

(vi) details of fixings to superstructures and substructures;

(vii) details of protective coatings;

(viii) methods of installation; and

(ix) programme of manufacture, testing and delivery, including name and address of testing laboratory.
23.5.4 **Representative Samples of Materials for Vehicular Parapets**

Representative samples of the proposed posts and rails for vehicular parapets shall be submitted to the Project Manager for review.

23.5.5 **Particulars of Movement Joints**

(a) The following particulars of the proposed movement joints shall be submitted to the Project Manager for review:

(i) details of type of movement joint and the name and address of the manufacturer;

(ii) design calculations and Contractor’s Drawings;

(iii) details of fixings, including the size, length and spacing of holding down bolts and any necessary revisions to the reinforcement;

(iv) details of materials for making good adjoining road surfaces and nosings, including reinforcement, jointing and curing details;

(v) programme of manufacture, testing and delivery; and

(vi) for fabricated movement joints, a written undertaking from the Contractor stating that the movement joint supplier shall install the proposed movement joint.

23.6 **WORKMANSHIP**

23.6.1 **Installation of Waterproofing Systems**

(a) Surfaces on which waterproofing systems will be laid shall be clean, dry and free from voids, loose aggregate, sharp protrusions, projecting tying wire, release agents and other items or substances which are likely to damage or affect the waterproofing system.

(b) Waterproofing systems shall be laid in accordance with the manufacturer's recommendations.

(c) Before waterproofing systems are laid on concrete surfaces, the concrete surface shall have been cured for at least 7 days and shall be cleaned with a broom and sealed with one coat of primer. Primed surfaces shall not be covered until the solvent constituent has evaporated. Water shall be allowed to evaporate from primers containing bituminous emulsion before the surface is covered. Primed surfaces shall be protected from contamination.

23.6.2 **Installation of Prefabricated Sheeting**

(a) Prefabricated sheeting shall be laid one sheet at a time from low points and drains, towards high points. The sheeting shall be firmly and tightly brought into contact with the primer or underlying sheeting.
(b) Laps shall be formed at joints between individual sheets of prefabricated sheeting. End laps shall be at least 150 mm and side laps shall be at least 100 mm. Joints shall be arranged in such a manner that the number of layers of sheeting at any joint does not exceed three.

(c) The perimeter of prefabricated sheeting laid each day shall be sealed with a trowelled bead of mastic.

(d) A double layer of prefabricated sheeting shall be laid around pipes, posts or other components which pass through the sheeting and the edges shall be sealed with a trowelled bead of mastic.

23.6.3 Installation of Bentonite Panels

(a) Bentonite panels shall not be laid in water or during wet weather.

(b) Immediately before bentonite panels are laid on a surface, joints and cracks in the surface shall be sealed with bentonite joint seal.

(c) Polyethylene sheeting shall be laid below and above bentonite panels to prevent prehydration. Laps of at least 100 mm shall be formed at joints in the sheeting.

(d) Laps shall be formed at the edges of bentonite panels or the edges shall be closely butted together and the seam filled with loose bentonite granules.

(e) Bentonite panels shall not be fixed to the underlying surface unless permitted by the Project Manager. If permitted, the method of fixing shall be by 25 mm masonry washerhead nails or by other methods reviewed without objection by the Project Manager.

(f) Bentonite panels shall be laid continuously around wall bases and corners. Flat panels shall not be folded or bent if the panels will be damaged or bentonite filler will be lost.

(g) Bentonite which is exposed at the edges of bentonite panels cut to fit around pipes, posts or other components which pass through the panel shall be taped or sealed by other methods reviewed without objection by the Project Manager to prevent loss of the bentonite filler. The joint between panels and the pipe, post or component shall be sealed with a continuous bentonite seal.

(h) Exposed bentonite panels shall be protected from moisture by polyethylene sheeting unless panels with a water repellent coating are used. The sheeting shall be removed before fill material is deposited. As soon as practicable after each course of panels has been laid, fill material shall be deposited and compacted up to a level which is within 50 mm of the top edge of the panel.

(i) Damaged or expanded bentonite panels shall be not be used.

23.6.4 Bituminous Paint Waterproofing Systems

Surfaces to which bituminous paint will be applied shall be treated with a primer before the paint is applied if recommended by the paint manufacturer. Bituminous paint shall be applied in two coats; the first coat shall be allowed to dry before the second coat is applied.
23.6.5 Installation of Bridge Bearings

(a) Bridge bearings shall be installed as recommended in BS 5400:Part 9 and as stated in Clauses 23.6.5(b) to (g).

(b) Bridge bearings which have been pre-assembled shall not be dis-assembled.

(c) The levels of substructures stated in the Contract on which bridge bearings will be installed shall be adjusted to suit the thickness of the bearing so that the superstructure will be at the specified level after completion.

(d) Bridge bearings, other than elastomeric bridge bearings, shall be set level on substructures using only a thin layer of cementitious mortar, unless the Project Manager permits the bearings to be set on plinths. If setting on plinths is permitted, the plinths shall be constructed of cementitious mortar or grout, unless otherwise reviewed without objection by the Project Manager, and the thickness of such plinths shall be at least 25 mm and shall not exceed 40 mm. If reviewed without objection by the Project Manager, the plinths may be constructed of chemical resin mortar, having a thickness of at least 5 mm and not exceeding 10 mm.

(e) Elastomeric bearings shall be set directly on the substructure. A thin layer of cementitious mortar may be used to level the surface if the substructure is concrete. Elastomeric bearings shall not be set in position by grouting between the substructure and the underside of the bearing.

(f) The top surface of bridge bearings which will support precast concrete or other prefabricated beams shall be covered with a thin layer of cementitious mortar immediately before the beam is placed. The beam shall be temporarily supported on folding wedges until the mortar has achieved sufficient strength to transmit the weight of the beam to the bearings. Thereafter the temporary supports shall be removed.

(g) Temporary locking devices for bridge bearings shall be removed before post-tensioned superstructures are stressed. Temporary locking devices for other types of superstructures shall be removed at times reviewed without objection by the Project Manager.

23.6.6 Tolerances: Bridge Bearings

(a) The centreline of bridge bearings shall be within 3 mm of the specified position.

(b) The level of bridge bearings shall be within 0.0001 times the adjacent span or the lesser of the adjacent spans or within 5 mm of the specified level, whichever is less.

(c) The inclination of bridge bearings shall be within 1 in 200 of the specified inclination.

(d) The horizontal axis of bridge bearings shall be within 0.005 radian of the specified alignment.

(e) Departure from the common plane between twin or multiple bridge bearings shall be within the tolerances stated in the Contract.
23.6.7 Installation of Vehicular Parapets

(a) Vehicular parapets shall be installed to a smooth alignment and with the posts vertical.

(b) Grouting shall be carried out by setting the vehicular parapets in position and grouting the gap between the vehicular parapets and the structure. Vehicular parapets shall be held in position until connections and fixings are complete and until the fixings have gained sufficient strength.

23.6.8 Tolerances: Vehicular Parapets

Vehicular parapets shall be within 10 mm of the specified position and height.

23.6.9 Installation of Fabricated Movement Joints

(a) Fabricated movement joints shall be installed in accordance with the manufacturer's recommendations. The Contractor shall provide that installation of the movement joint shall be carried out by the supplier of the movement joint.

(b) The vertical faces of recesses in bridge decks for fabricated movement joints shall be formed by saw-cutting. Holding-down bolts shall be cast into the concrete for direct mounting of the joints unless the Project Manager permits the bolts to be grouted. If grouting is permitted, the grouting shall be carried out by setting the movement joint in position and grouting the gap between the movement joint and the structure. Rebates and pockets for subsequent trimming to line and level or for holding-down bolts shall not be used.

(c) The bedding to fabricated movement joints shall be formed such that there shall be no gaps between the joint and the bedding.

(d) Relative movement between components and supports of a fabricated movement joint shall be prevented during installation of the joint and during placing and hardening of concrete and mortar under the components. Joint components shall be free to move longitudinally relative to each other.

(e) When one side of a fabricated movement joint is being set, the other side shall be free from longitudinal restraint. Strongbacks or templates used to locate the sides of a joint shall not be fixed to both sides at any one time.

23.6.10 Road Surface Adjoining Fabricated Movement Joints

(a) The gap between fabricated movement joints and the adjoining road surface or nosing shall be made good after installation of the joint with material which has properties as similar as practicable to those of the material in the adjoining road surface.

(b) Bituminous road surfaces shall be made good with a bituminous mixture or elastomeric concrete. Concrete road surfaces shall be made good with a cementitious matrix reinforced with metal or glass fibres or with elastomeric or polymer concrete. Epoxy resin mortar shall not be used.

(c) Elastomeric and polymer concrete shall be prepared, laid and cured in accordance with the manufacturer's recommendations.
23.6.11 Protection of Fabricated Movement Joints

(a) The Project Manager shall be notified before Contractor's Equipment or other vehicles cross a fabricated movement joint or the adjacent road surface.

(b) Contractor's Equipment or other vehicles shall not cross fabricated movement joints or adjacent road surfaces until installation of the joint is complete unless reviewed without objection by the Project Manager. Ramps shall be provided to allow the vehicles to cross without loads being applied to the joint.

23.6.12 Forming Movement Joints

Gaps forming part of movement joints formed in place shall be filled with joint filler fixed in position with adhesive. The edge of the joint filler shall be covered with bond breaker tape or a PVC capping strip.

23.6.13 Forming Grooves

Grooves for joint sealant and compression seals for movement joints formed in place shall be formed by saw cutting.

23.6.14 Sealing Grooves

Grooves for movement joints formed in place shall be sealed with joint sealant or with a compression seal.

23.6.15 Tolerances: Fabricated Movement Joints

The surface of fabricated movement joints shall be at least 1 mm, and not more than 3 mm, below the surrounding road surface.

23.7 INSPECTION TESTING AND COMMISSIONING

23.7.1 Testing: Bridge Bearings

(a) Bridge bearings shall be tested by the Contractor at a laboratory reviewed without objection by the Project Manager.

(b) The Contractor shall inform the Project Manager of the date and place of testing at least 28 days before testing starts.

(c) The procedures for testing bridge bearings shall be submitted to the Project Manager for review and thereafter shall not be changed.

(d) The reports of tests on bridge bearings shall include load/deflection graphs and shall be submitted to the Project Manager for review at least 28 days before installation of the bridge bearings is programmed to start.

23.7.2 Samples: Friction Test for Bridge Bearings

One sample of bridge bearing shall be provided from each batch of sliding bearings and from each batch of other types of bridge bearings which contain sliding parts.
23.7.3 Testing: Friction Test for Bridge Bearings

(a) The friction test shall be carried out on each sample of bridge bearing provided as stated in Clause 23.7.2 to determine the coefficient of friction, flatness, bonding properties and resistance to mechanical damage. The method of testing shall be in accordance with Appendix A23.1.

(b) The friction test shall be carried out at room temperature.

23.7.4 Compliance Criteria: Friction Test for Bridge Bearings

(a) The results of friction tests for bridge bearings shall comply with the following requirements:

(i) the coefficient of friction in any test position shall not exceed 0.04;

(ii) the flatness of the stainless steel shall be within the specified limits after testing;

(iii) the bond to the backing plate shall be unaffected by the friction test; and

(iv) PTFE shall be free from mechanical damage after testing.

23.7.5 Samples: Bridge Bearings other than Elastomeric Bearings

One sample of bridge bearing shall be provided from each batch of bridge bearings other than elastomeric bearings.

23.7.6 Testing: Bridge Bearings other than Elastomeric Bearings

Vertical load tests and horizontal load tests shall be carried out on each sample of bridge bearing provided as stated in Clause 23.7.5. The test loads shall be the serviceability limit state loads. The method of testing shall be in accordance with Clause 7.2(b)(1) of the guidance notes to BS 5400:Section 9.2.

23.7.7 Compliance criteria: Bridge Bearings other than Elastomeric Bearings

The results of tests on bridge bearings other than elastomeric bearings shall comply with the requirements stated in Clause 7.2(b)(1) of the guidance notes to BS 5400:Section 9.2.

23.7.8 Samples: Elastomeric Bearings

(a) Except as stated in Clause 23.7.8(b), one sample of elastomeric bearing shall be provided from each batch of elastomeric bearings for testing by the "Quick Production Test".

(b) If the Contractor considers there is sufficient evidence that “Quick Production Tests” have been successfully completed on identical materials in the previous 18 months he may submit the evidence to the Project Manager and propose that the tests are not necessary. The Project Manager will respond within 14 days of the date of receipt of the submission.

(c) Two samples of elastomeric bearings shall be provided from each batch of ten or part thereof of elastomeric bearings to determine the stiffness in compression and stiffness in shear.
23.7.9 Testing: Elastomeric Bearings

(a) Each sample of elastomeric bearing provided as stated in Clause 23.7.8(a) shall be tested to determine the physical and weathering properties of the elastomer and the bond of the elastomer to metal. The method of testing shall be the "Quick Production Test" in accordance with the guidance notes to BS 5400:Section 9.2.

(b) One sample of elastomeric bearing provided as stated in Clause 23.7.8(c) shall be tested to determine the stiffness in compression and the other sample shall be tested to determine the stiffness in shear. The method of testing to determine the stiffness in compression shall be in accordance with Clause 7.2(b)(2) of the guidance notes to BS 5400:Section 9.2. The method of testing to determine the stiffness in compression shall be in accordance with BS 5400:Section 9.2, Appendix A.

23.7.10 Compliance Criteria : Elastomeric Bearings

(a) The results of tests on elastomeric bearings shall comply with the following requirements:

(i) There shall be no evidence of surface flaws in the bearings during or after the test;

(ii) There shall be no irregularities in the deflected shape of laminated bearings during or after the test;

(iii) The stiffness in compression shall be within 20% of the value quoted by the manufacturer and reviewed without objection by the Project Manager; and

(iv) The stiffness in shear shall be within 20% of the value quoted by the manufacturer and reviewed without objection by the Project Manager.
APPENDIX A23.1

FRICTION TEST FOR BRIDGE BEARINGS

A23.1.1 Scope

This method covers the determination of the coefficient of friction, flatness, bonding properties and resistance to mechanical damage of bridge bearings by means of a friction test.

A23.1.2 Equipment

(a) The following equipment is required:

(i) compression testing rig;

(ii) test loads;

(iii) equipment for measuring the loads applied, readable and accurate to within 2% of the measured load;

(iv) equipment for measuring movement, readable and accurate to 0.01 mm; and

(v) lubricant of the same type as will be used in service.

A23.1.3 Procedure

(a) The procedure shall be as follows:

(i) the PTFE surface of the bearing shall be lubricated with the lubricant;

(ii) two sets of sliding surfaces shall be mounted back to back between the platens of the compression testing rig with the stainless steel sliding surfaces in the center;

(iii) a vertical load equal to the permanent load stated in the schedule of bearings shall be applied for 1 hour;

(iv) a horizontal load shall then be applied steadily and without shock to the pair of stainless steel sliding surfaces and shall be increased at a rate of 0.2% of the vertical load per minute until movement occurs between the sliding surfaces;

(v) the maximum horizontal load sufficient to cause movement of at least 25 mm between the stainless steel and PTFE sliding surfaces at a rate not exceeding 50 mm/min shall be recorded;

(vi) the loads shall be removed; and

(vii) the sliding surfaces shall be removed from the rig and inspected.
A23.1.4 Calculation

(a) The coefficient of friction shall be calculated from the equation:

\[
\text{Coefficient of friction} = \frac{\text{Maximum horizontal force}}{2 \times \text{vertical load}}
\]

A23.1.5 Reporting of results

(a) The following shall be reported:

(i) name of bearing manufacturer;
(ii) details of bearing and sliding surfaces;
(iii) the vertical load applied;
(iv) the maximum horizontal force applied;
(v) the total movement and rate of movement at the maximum horizontal force applied;
(vi) the coefficient of friction to two significant figures;
(vii) details of any damage to the sliding surfaces; and
(viii) that the test method used was in accordance with this General Materials and Workmanship Specification.
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SECTION 24  WATER RETAINING STRUCTURES

24.1 GENERAL

(a) The works and materials specified below shall comply with the sections stated, unless otherwise stated in this Section.

(i) earthworks shall comply with Section 7;

(ii) formwork and finishes to concrete shall comply with Section 18;

(iii) steel reinforcement shall comply with Section 19;

(iv) concrete shall comply with Section 20;

(v) joints in concrete shall comply with Section 20; and

(vi) drainage systems shall comply with Section 6.

24.2 DEFINITIONS AND ABBREVIATIONS

24.2.1 Water Retaining Structure

Water retaining structure is a structure, or part of a structure, including walls, floors, roofs, columns and footings, which is stated in the Contract to be constructed for storing, conveying or excluding water, sewage or other aqueous liquids.

24.3 MATERIALS

24.3.1 Sliding Layers

Sliding layers below floor slabs of water retaining structures shall be a proprietary type of polyethylene sheeting reviewed without objection by the Project Manager. Polyethylene sheeting shall be impermeable and shall have a nominal thickness of 1.1 mm.

24.4 SUBMISSIONS

24.4.1 Particulars of Sliding Layers

Particulars of the source and type of proposed sliding layers for water retaining structures shall be submitted to the Project Manager for review.

24.4.2 Particulars of Materials and Methods of Construction for Water Retaining Structures

(a) The following particulars of the proposed materials and methods of construction for water retaining structures shall be submitted to the Project Manager for review:

(i) sequence and method of concreting bays in floor slabs, walls and roof slabs and in columns and footings;
(ii) details of alternative locations of construction joints if required;

(iii) details of type and size of waterstops at construction joints and box-outs;

(iv) sequence and method of testing roofs for watertightness; and

(v) details of method of testing water retaining structures for watertightness including:
   - arrangement of pumps and equipment;
   - source of water;
   - equipment for measuring fall in water level;
   - device for dampening the oscillatory motion of the water surface;
   - filling rate; and
   - method of correction for evaporation and rainfall.

24.4.3 Representative Samples of Sliding Layers

Representative samples of the proposed sliding layers for water retaining structures shall be submitted to the Project Manager for review.

24.5 WORKMANSHIP

24.5.1 Drainage Systems

Measures shall be taken to prevent concrete and deleterious material from being deposited in drainage systems under floors and on roofs of water retaining structures. After construction and before testing, the drainage system shall be thoroughly cleaned by rodding and flushing to remove any deleterious material which may impede the flow of water into or through the drainage system. The lines and levels of drainage systems shall be within 20 mm of the specified horizontal alignment and within 10 mm of the specified vertical alignment.

24.5.2 Laying Sliding Layers

Polyethylene sheeting in sliding layers below floor slabs of water retaining structures shall be laid flat without creases. Laps shall be at least 225 mm and there shall be no gaps at the edges of bays.

24.5.3 Floor Slabs of Water Retaining Structures

Except as otherwise stated on the Employer's Drawings, if reinforcement is continuous across the joint between bays in the floor slab of water retaining structures, the bays shall be concreted contiguously, in sequence, with a minimum period of 48 hours between completion of concreting one bay and commencement of concreting the adjacent bay.

24.5.4 Walls of Water Retaining Structures

(a) Except as otherwise stated on the Employer's Drawings, if reinforcement is continuous across the joint between bays in the wall of water retaining structures, the bays shall be concreted contiguously, in sequence, with a minimum period of 72 hours between the completion of concreting the lift in one bay and commencement of concreting the adjacent lift in the adjacent bay.
(b) The first lift in each bay in the walls of water retaining structures shall be concreted within seven days after completion of concreting the adjacent base of the wall. Individual lifts shall be concreted in one continuous operation without cold joints, whether or not the full height of the wall is concreted in one lift. If the full height of the wall is not placed in one lift, succeeding lifts shall be concreted within seven days from concreting of the adjacent lift.

24.5.5 **Roof Slabs of Water Retaining Structures**

If reinforcement is continuous across the joint between bays in the roof slab of water retaining structures, the bays shall be concreted contiguously, in sequence, with a minimum period of 48 hours between completion of concreting one bay and commencement of concreting the adjacent bay.

24.5.6 **Built-in Pipes in Water Retaining Structures**

Unless otherwise stated in the Contract, puddle flanges on built-in pipes in water retaining structures shall be located centrally within the formwork. Waterstops shall be fixed around the perimeter of box-outs to the built-in pipes.

24.5.7 **Protection of Water Retaining Structures**

(a) Immediately after the roof slab of water retaining structures has been tested, the slab shall be protected with damp sacks or by other methods reviewed without objection by the Project Manager from exposure to conditions which may affect the slab; the protection shall be continued until the roof drainage system has been constructed or the fill material has been deposited and compacted.

(b) Materials shall not be stockpiled on roof slabs of water retaining structures. Contractor's Equipment or other vehicles shall not stand or run on floor slabs or roof slabs of water retaining structures.

24.5.8 **Deposition of Fill Material**

(a) Fill material shall not be deposited behind sections of walls of water retaining structures until at least seven days after completion of concreting to the section of wall.

(b) Fill material shall be spread out evenly and shall not be stockpiled on roofs to water retaining structures. Weed killer or other chemicals shall not be applied to fill material on the roofs of water retaining structures for potable or fresh water.

(c) Deposition of fill material on or adjacent to water retaining structures shall be carried out after the watertightness test on the structure has been completed.

24.5.9 **Cleaning and Sterilisation of Water Retaining Structures**

(a) Immediately before water retaining structures are tested for watertightness, all dust, debris, unused materials and equipment shall be removed from the structure and the interior of the structure shall be washed and brushed down with water.

(b) Water for washing water retaining structures for potable or fresh water shall be fresh, potable water incorporating a mixture of sterilising chemicals added before the structure is washed at a concentration reviewed without objection by the Project Manager. The structure shall be maintained in a clean condition after cleaning.
24.6 INSPECTION TESTING AND COMMISSIONING

24.6.1 Testing: Drainage Systems for Water Retaining Structures

(a) Drainage systems under floors and on roofs of water retaining structures shall be tested in accordance with the following requirements:

   (i) water shall be poured at different locations directed by the Project Manager along the drainage system and the flow of water observed at junction pits, outfalls and other discharge points; and

   (ii) a mandrel shall be pulled through each completed section of pipeline of 300 mm diameter or less. The mandrel shall be 750 mm long and 12 mm less in diameter than the nominal diameter of the pipe.

24.6.2 Compliance Criteria: Drainage Systems for Water Retaining Structures

(a) The results of tests on drainage systems for water retaining structures shall comply with the following requirements:

   (i) water shall be freely discharged by the drainage system; and

   (ii) bore, linearity and jointing of pipes shall comply with the specified requirements.

24.6.3 Non-compliance: Drainage Systems for Water Retaining Structures

If the result of any test on the drainage system for water retaining structures does not comply with the specified requirements for the test, the Contractor shall investigate the reason. Remedial or replacement work reviewed without objection by the Project Manager shall be carried out and the drainage system shall be retested.

24.6.4 Testing: Watertightness of Roofs

(a) The roofs of water retaining structures shall be tested for watertightness over the complete area of the roof, including perimeter joints. Roofs shall not be tested in sections.

(b) Water shall be ponded on the roof for a period of three days and topped up to maintain a depth of at least 75 mm. The test shall be carried out before fill material is deposited or drainage systems are constructed on the roof.

24.6.5 Compliance Criteria: Watertightness of Roofs

There shall be no leaks or damp patches visible on the soffits of roofs of water retaining structures during or at the end of the test for watertightness.

24.6.6 Non-compliance: Watertightness of Roofs

If the result of any test for watertightness of the roof of a water retaining structure does not comply with the specified requirements for the test, the Contractor shall investigate the reason. Remedial or replacement work reviewed without objection by the Project Manager shall be carried out and the roof shall be retested.
24.6.7 Testing: Watertightness of Structures

(a) Water retaining structures shall be tested for watertightness as stated in Clause 24.6.7 (b) to (g). Each compartment of structures which incorporate division walls shall be tested separately with adjoining compartments empty and the complete structure shall also be tested.

(b) The structure shall be filled with water at an approximately uniform rate not exceeding 2 m depth in 24 hours to the levels stated in Table 24.1. The water used for testing water retaining structures for potable or fresh water shall be fresh potable water. The Project Manager shall be notified before filling starts. The structure or each compartment of the structure being tested shall be kept full for 7 days before testing to allow for absorption.

(c) After the period for absorption, the water shall be topped up to the specified level and the test shall begin. During testing, the oscillatory motion of the water surface shall be dampened. The test period shall be 7 days.

(d) The equipment for recording water levels shall be installed in a temporary enclosure of minimum dimensions 2 m x 2 m x 2.5 m high with a lockable door; the enclosure shall be located over stilling wells, manhole openings or other points of recording water levels. The temporary enclosure shall be removed on completion of the test. The equipment shall be calibrated before testing starts and at regular intervals reviewed without objection by the Project Manager and shall be readable and accurate to 0.5 mm.

(e) The fall in water level in water retaining structures shall be measured at hourly intervals between 8 a.m. and 5 p.m. each day; the total fall shall be measured at the end of the test period.

(f) Except as stated in Clause 24.6.7(g), structures shall be emptied after completion of testing and maintained in a clean and dry condition. The water shall be removed at an approximately uniform rate not exceeding 2 m depth in 24 hours. The Project Manager shall be notified before emptying starts.

(g) The water used for the final tests on water retaining structures for potable or fresh water shall be retained in the structure and shall not be wasted or contaminated.

24.6.8 Compliance Criteria: Watertightness of Structures

(a) The results of tests for watertightness of water retaining structures shall comply with the following requirements:

(i) the total fall in water level at the end of the test period, after adjustment for evaporation and rainfall, shall not exceed 1/500 times the maximum specified depth of water in the test or 10 mm, whichever is less; and

(ii) there shall be no leaks or damp patches visible on the surface of the structure, including any division walls, during or at the end of the test.
24.6.9 Non-compliance: Watertightness of Structures

If the result of any test for watertightness of a water retaining structure does not comply with the specified requirements for the test, the Contractor shall investigate the reason. Remedial or replacement work reviewed without objection by the Project Manager shall be carried out and the structure shall be retested.

Table 24.1: Test on Water Retaining Structures

<table>
<thead>
<tr>
<th>Type of structure</th>
<th>Part of structure tested</th>
<th>Test water level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water retaining structures other than for</td>
<td>Structure with division wall</td>
<td>100 mm below top of division wall</td>
</tr>
<tr>
<td>sewage</td>
<td>- each compartment of structure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Structure with division wall</td>
<td>Top water level of structure</td>
</tr>
<tr>
<td></td>
<td>- complete structure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Structure without division wall</td>
<td></td>
</tr>
<tr>
<td>Water retaining structures for sewage</td>
<td>Structure with division wall</td>
<td>Top water level of structure</td>
</tr>
<tr>
<td></td>
<td>- each compartment of structure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Structure with division wall</td>
<td>Top water level of structure</td>
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<tr>
<td></td>
<td>- complete structure</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Structure without division wall</td>
<td></td>
</tr>
</tbody>
</table>

24.6.10 Samples: Water Sterilisation

After the test for watertightness of a water retaining structure for potable or fresh water has been completed, samples of the water in the structure shall be taken by the Contractor in the presence of the Project Manager. The number of samples and location of sampling shall be reviewed without objection by the Project Manager.

24.6.11 Testing: Water Sterilisation

Each sample of water shall be tested to determine the bacteriological content.

24.6.12 Compliance criteria: Water Sterilisation

The results of tests for bacteriological content of the water shall demonstrate that the structure has been adequately sterilized in compliance with the requirements of the Contract and the Relevant Authorities.