

Hong Kong Shooting
Association

**Proposed Shooting
Range at Pillar Point**

Standard Specification
for Structural Concrete

ARUP

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1 GENERAL

1.1 Abbreviations

Abbreviations used in this Specification for Structural Concrete shall have the following meanings:

AAR	Alkali-aggregate Reaction
ASTM	American Society for Testing and Materials
BD	Buildings Department
BS	British Standard
BS EN and BS EN ISO	European Standard adopted as British Standard
HKCC	Hong Kong Code of Practice for Structural Use of Concrete 2004
CS1	Hong Kong Construction Standards CS1 – Testing Concrete
CS2	Hong Kong Construction Standards CS2 – Carbon Steel Bars for the Reinforcement of Concrete
GGBS	Ground Granulated Blastfurnace Slag
GRP	Glass-reinforced Plastic
HKB(C)R	Hong Kong Building (Construction) Regulations
HKQAA	Hong Kong Quality Assurance Agency
HOKLAS	Hong Kong Laboratory Accreditation Scheme
ICE	Independent Checking Engineer
IRSE	Independent Registered Structural Engineer appointed by the Contractor and approved by the Architect
ISO	International Organization for Standardization
PC	Portland Cement – CEM I cement to BS EN 197-1
PFA	Pulverised Fuel Ash
PNAP	Practice Notes for Authorized Persons and Registered Structural Engineers
PPFAC	Portland Pulverised Fuel Ash Cement – CEM II/A-V, CEM II/A-W, CEM II/B-V and CEM II/B-W cement to BS EN 197-1
QSPSC	Quality Scheme for the Production and Supply of Concrete
RILEM	Reunion Internationale des Laboratoires et Experts des Matériaux, Systèmes de Construction et Ouvrages (International Union of Laboratories and Experts in Construction Materials, Systems, and Structure)
RSE	Registered Structural Engineer
SCM	Secondary Cementitious Materials
TCP	Technical Competent Person
TFV	Ten percent Fines Value

1.2 Definitions

1.2.1 Designed Mixes

"Designed mixes" shall mean any concrete mix where the specified constituents are individually proportioned and purposely combined to achieve the design compressive strength or to satisfy other specified requirements of the concrete.

1.2.2 Prescribed Mixes

"Prescribed mixes" shall mean a concrete mix as defined in Regulation 60 of the HKB(C)R.

1.2.3 Concrete Grade

For designed mixes, the concrete grade shall mean the design compressive strength of the concrete as determined by Regulations 58 and 59 of the HKB(C)R when tested to CS1. In certain cases, the grades may be suffixed alphabetically to differentiate between similar grades but for different uses.

For prescribed mixes, the concrete grade designation will denote concrete as defined in Regulation 60 of the HKB(C)R and will be used only for minor structures or non-structural works.

1.2.4 Building Regulations and Standards

Unless stated otherwise, all undated references to Building Regulations and various standards cited in this Specification refer to the editions (including any amendments) current at the time of Tender. For dated references, only the edition cited applies. Reference to a Code or Standard shall be deemed to include all other Codes and Standards referred to in the specified Code or Standard.

1.2.5 Falsework

The temporary structure used to support a permanent structure until it is self supporting.

1.2.6 Formwork

The part of the falsework used to give the required shape, finish and support to the poured concrete.

1.3 Hong Kong Building Regulations and Code of Practice

This Specification shall be read in conjunction with the HKCC, PNAP(s) and Practice Notes for Registered Contractors which cover the implementation of the Hong Kong Building Regulations. In cases of conflict, the more onerous requirement shall prevail.

In this Specification, Hong Kong Building Regulations include the current editions of the Building Ordinance, Building (Administration) Regulations, Building (Planning) Regulations and Building (Construction) Regulations.

1.4 General Description of Concrete Works

The reinforced concrete works of the Contract are designed in accordance with current edition of the HKB(C)R, relevant PNAP(s) and HKCC.

The Works shall include all the concrete works shown or described in the Tender Documents, and as modified or added during the Contract. The works may consist of different grades and usage of concrete including concrete for water-resisting construction. These usages will be shown on the Architectural or Structural Drawings.

Read this Specification in conjunction with the General Contract Preliminaries and all other Contract Documents.

1.5 Co-ordination of Works

The Contractor shall be fully conversant with all the drawings and other information on the Works including mechanical, electrical and utility drawings and specifications to be carried out by Sub-contractors and Specialist Contractors.

The Contractor shall coordinate and make necessary provisions for any holes, cast-in items and embedded pipes or conduits etc. by all Sub-contractors and Specialist Contractors. The location and routing of such which would affect the structures shall be subject to Architect's approval.

2 MATERIALS

2.1 General

2.1.1 Quality of Materials

All materials used in the structure shall be new and shall be of the quality and grades comply with this Specification and current versions of standards referred to therein. The Architect may specify samples for testing and the Contractor shall arrange for such samples to be supplied, identified, stored and tested and the results delivered to the Architect in accordance with the relevant HKB(C)R and BS.

2.1.2 Materials to be Approved

Where this Specification and the Drawings allow the Contractor a choice of materials to be used in the Works, the materials chosen and their proposed sources of supply shall be subject to approval in writing by the Architect.

The proposed sources of supply shall be accompanied by test certificates from the supplier showing that the materials comply with the specified requirements. Any change of sources shall be subject to approval in writing by the Architect.

The fact that the Contractor has used materials to the approval of the Architect shall in no way relieve him from his responsibility of producing a concrete of the required characteristics as stipulated in this Specification such as grade strength, workability and etc. for the purpose to which it is placed.

2.1.3 Materials to Comply With Relevant Standards

Where a Hong Kong or International Standard is applicable, the materials used for the Works shall comply with the relevant standard. In general, the Standard adopted by the manufacturer of a material shall be considered, unless the Engineer's design is based on a particular Standard, in which case that Standard shall be used for assessment of the material.

A copy of all relevant standards shall be provided by the Contractor and kept on site at all times.

2.2 Cement

Cement used for making concrete shall be PC or blended PPFAC containing PFA at a nominal content of 25% by weight. Other cements shall only be used when approved by the Architect.

When required by the Architect, the Contractor shall submit for approval the technical data of the cement including the mix proportion before cement grinding (the percentage of clinker, gypsum and underground materials) and the results of composition analysis. The composition analysis shall at least include CaO, MgO, SiO₂, Al₂O₃, Fe₂O₃, SO₃, alkalis as K₂O and Na₂O, free lime as CaO, acid insoluble residue, loss of ignition and the calculated mineral phase constituents (by Bogue).

All cement to be used on the Works shall be supplied from the same source unless alternate sources are approved by the Architect.

All cement to be used on the Works shall be delivered in the original sealed and branded bags of the manufacturer or in bulk containers approved by the Architect.

2.3 Secondary Cementitious Materials (SCM)

Subject to approval from the BD and the Architect, SCM, including PFA, GGBS and microsilica (silica fume), or any combination of two, may be used with PC in concrete.

PFA shall comply with BS 3892-1: 1997, except that the criterion for maximum water requirement may not apply. GGBS shall comply with BS 6699 (BS EN 15167-1 may be

used to replace BS 6699). Microsilica shall comply with Canadian Standard CAN/CSA-A23.5-98 or ASTM C1240-05.

The use of such SCM shall comply with the requirements in HKB(C)R and PNAP.

2.4 Aggregates

2.4.1 General

The Contractor shall submit to the Architect for approval details of his proposed source of supply of aggregates giving the aggregate group classification and typical physical and chemical properties complying with BS EN 12620 unless otherwise specified in this Specification. The Contractor may, in special circumstances, propose variations from the grading shown in BS EN 12620; such proposals shall be subject to approval in writing by the Architect.

The grading of aggregates should be such as to produce a dense concrete of the specified proportions which will work readily into position without segregation. The grading should be controlled throughout the work so that it conforms closely to that used for the preliminary tests.

The definition and particle size distribution of fine aggregate and coarse aggregate shall comply with BS EN 12620 and BS 812-103.1 (BS EN 933-1 may be used to replace BS 812-103.1).

2.4.2 Uniformity

The Contractor shall obtain an undertaking from the suppliers of both fine and coarse aggregates of the quality and type selected that sufficient supplies are available to complete the Contract, and that the aggregates come from a single source. This source shall be subject to approval in writing by the Architect. The Architect shall be notified prior to any change in the source of supply of aggregate.

2.4.3 Shape, Strength and Porosity

Coarse aggregate shall have a flakiness index not exceeding 30% when tested by the sieve method of BS 812-105.1.

Coarse aggregate shall have an elongation index not exceeding 35% when tested in accordance with BS 812-105.2.

The ten percent fines values shall be at least 100kN when tested in accordance with BS 812-111.

The water absorption of coarse aggregates shall not exceed 2.5% by weight, unless evidence is produced to show that such materials are not available.

2.4.4 Marine Aggregates

Marine aggregates shall not be used without prior approval by the Architect.

2.4.5 Salts

The total amount of soluble salts and chloride contents in the aggregates shall not exceed the limits in Table 2.1 when tested to BS 812-117:

Table 2.1

Type of Aggregate	Sodium Chloride Content as % by Weight of the Dry Aggregate
Fine	0.08
Coarse	0.04

2.4.6 Control of Aggregate Alkali-Reactivity

The Contractor shall carry out tests on all aggregate for potential alkali-reactivity by an independent laboratory approved by the Architect using the 'Accelerated Mortar Bar Test' to RILEM AAR-2. The aggregate shall be considered acceptable if the average expansion

result at 16 days is less than 0.15%. Each aggregate shall be tested initially, prior to supply, and then at a minimum frequency of twice per year. At the discretion of the Architect, the aggregate shall be examined petrographically with respect to alkali aggregate reactivity and other deleterious substance by a qualified geologist.

2.5 Water

Potable water which complies with BS 3148 shall be used for mixing and curing concrete. If suitable potable water is not available (i.e. non-compliance to BS 3148) then the alternative source or mix design with corresponding inhibitors (e.g. corrosion inhibitors) shall be proposed and is to be approved in writing by the Architect.

When so directed, the Contractor shall arrange for tests of the water to be carried out in accordance with BS 3148.

The water used for flaked ice for the control of concrete mixing temperature should also be tested in accordance with BS 3148 if it comes from a non-potable source.

BS EN 1008 may be used to replace BS 3148.

2.6 Admixtures

Admixtures may be permitted in designed mixes at the Architect's discretion, after satisfactory details of the admixtures and the associated mix design and trial results have been submitted by the Contractor.

Admixtures will not be permitted in prescribed mixes unless otherwise approved by the Architect.

Admixtures containing calcium chloride will not be permitted.

All admixtures shall comply with BS EN 480 and BS EN 934 and shall be accompanied by manufacturer's performance and uniformity tests certificates. Admixtures shall be used in accordance with the manufacturer's instructions.

The Contractor should also refer to the Architect's specifications and drawings for details of the water-resisting additives proposed for the various elements.

The Contractor's attention is particularly drawn to Clause 3.15 on water-resisting construction responsibilities and recommendations.

2.7 Curing Compound

Where used, curing compounds for concrete shall have a minimum efficiency index of at least 80%. The Contractor shall provide the test certificates prepared by an approved laboratory to show that the compound will provide the required curing efficiency.

Curing compound shall not react chemically with the concrete to be cured and shall not crack, peel or disintegrate during the curing period of at least seven days. The curing compound shall degrade completely within three weeks after application and the concrete surface so treated shall not impair the bonding of applied finishes, otherwise, the Contractor shall justify with confirmation from the manufacturer the compatibility with the surface finishes to the satisfaction of the Architect.

Curing compound for use on concrete surface against which potable or fresh water will be stored or conveyed shall be non-toxic and shall not impart a taste to the water.

2.8 Concrete

2.8.1 General

Concrete shall be made with cementitious material, coarse and fine aggregates and water. No other ingredients shall be used by the Contractor or Concrete Supplier without

demonstrating compliance of such ingredients and the concrete mix with the requirements of the BD, as well as the Architect's approval.

Unless otherwise approved by the Architect, ready-mixed concrete used for the Works shall only come from an approved concrete supplier. No change of supplier shall be allowed without approval from the Architect.

The Contractor shall also refer to Section 5 for High Strength Concretes (Grade 60-100 MPa).

2.8.2 Designed Mix Concrete

Designed mixes, with proportions calculated by the Contractor (guidelines given in Table 2.2), shall be used for each concrete grade as specified on the Drawings. Complete details shall be submitted for approval of the Architect and, if necessary, of the BD before commencement of concreting work.

As far as possible, PFA could be used in structural concrete in complying with Clause 4.2.5.5 of HKCC. All structural concrete of Grade 40 to Grades below 60 for structural elements with thickness of 2m and above, and of Grade 60 and above shall contain a nominal PFA content of 25% by weight of total cementitious material unless evidence can be produced to show that PFA or PPFAC is not available. PFA shall not be used separately as a SCM together with PPFAC.

This Specification shall take precedence over the mix limitations specified in Part XII (Structural Use of Concrete) of the HKB(C)R.

Table 2.2: Designed Mixes

Grade	28-Day Works Strength (N/mm ²)	Maximum Coarse Aggregate Size (mm)	Maximum Water/ Cementitious Ratio	Minimum Cementitious Content (kg/m ³)	Maximum Cementitious Content (kg/m ³)	Other Requirement
20D	20	20	0.55	290	360	-
25D	25	20	0.50	290	360	-
30D	30	20	0.50	290	360	-
40D	40	20	0.45	340	450	-
45D	45	20	0.45	340	450	See Notes
50D	50	20	0.40	380	500	See Notes
30D(W)	30	20	0.45	360	400	Water-resisting Construction
40D(W)	40	20	0.45	360	420	Water-resisting Construction
45D(W)	45	20	0.42	360	440	Water-resisting Construction
50D(W)	50	20	0.40	400	520	Water-resisting Construction
<p>Notes: The mix should be designed using a Standard Deviation of not less than 7 MPa.</p> <p>The Contractor shall satisfy himself that the mix proportions specified for use in water-resisting construction are suitable for the aggregate available.</p> <p>Under normal circumstances, the cement content shall be limited to not more than 450 kg/m³.</p> <p>Concrete of Grade 45 to Grades below 60 shall use coarse aggregate having a 10% fines value of not less than 150kN when tested dry.</p>						

When using a maximum aggregate size of 10mm and 14mm, the minimum cementitious contents specified in Table 2.2 shall be increased by 40 kg/m³ and 20 kg/m³ respectively.

In certain circumstance, coarse aggregate of a maximum size up to 40mm may be used providing the Contractor has obtained the written agreement from the Architect beforehand. When using a maximum aggregate size of 40mm, the minimum cementitious contents specified in Table 2.2 shall be decreased by 30 kg/m³.

Concrete used for Water-resisting Construction (W) shall use coarse aggregates having combined indices for flakiness and elongation not exceeding 50% and the flakiness index shall not exceed 25%.

Pumped mix concrete shall have a minimum slump of 150mm. High Flow Concrete shall achieve a minimum slump-flow value of 600mm within one minute and without evidence of segregation. Self Compacting Concrete shall achieve a minimum slump-flow value of 700mm within two minutes without segregation and a flow to 500mm in 15 seconds. The concrete shall retain this slump-flow performance for a minimum period of 2 hours after mixing. See also Clause 4.6.6.

Regardless of the limitations of the proportions in Table 2.2, at any time during the progress of the Works the Architect shall have the right to make such changes in the materials or proportions or both as he may consider necessary to meet the requirements of the structure.

2.8.3 Prescribed Mix Concrete

Prescribed mix concrete shall be in accordance with Regulation 60 of the HKB(C)R.

All materials for concrete shall be measured by weight. The workability of the mix shall be determined by the Contractor and shall have a slump not less than 75mm.

2.8.4 Trial Mixes

Preliminary tests shall be done in accordance with BS 8500 and BS EN 206-1.

Results of all preliminary tests shall be sent to the Architect as soon as they are available and at least 35 days before concrete work starts on site.

The Architect may not accept the results of tests on trial mixes produced in a laboratory if he is not satisfied that they are representative of the quality of concrete produced for the Works.

Plant trials shall be carried out, at the Architect's discretion, using the same equipment and at the same plant intended for supply of the concrete. Each plant trial mix shall be carried out on three separate days and the minimum size of each batch shall be 60% of the mixer's nominal capacity or 1m³ whichever is the bigger.

Two 150mm test cubes shall be made for 3, 7 and 28 days compressive strength test in accordance with CS1 for each batch of concrete. The 28 days results shall comply with the following criteria for acceptance of the trial mix:

- (a) The mean strength of the 28 days results shall exceed the characteristic strength plus 10 MPa for plant trial or 12 MPa for laboratory trial.
- (b) No single result shall fall below the characteristic strength plus 5 MPa.

Two slump or compacting factor tests shall be carried out in each batch of the trial. For slump with design value < 100mm, the tolerance shall be within ± 20 mm or $\pm 25\%$ of the design value whichever is more stringent. For slump with design value ≥ 100 mm, the tolerance shall be within ± 40 mm or $\pm 25\%$ of the design value whichever is more stringent. The average of the slump value shall be within ± 20 mm, and the range of the slump value for each batch of concrete shall not exceed 20% of the average slump value for that batch. The acceptance criterion of the compacting factor shall be the design compacting factor ± 0.03 .

No concrete shall be placed in the permanent Works until the concrete mix and trial mix results have been reviewed and accepted by the Architect.

2.8.5 Ready-Mixed Concrete

The onus is on the Contractor to ensure that all concrete is strictly in accordance with the requirement of this Specification. The Contractor shall arrange for the Architect to inspect the supplier's plant if required before and/or during the period of supply.

Concrete suppliers shall operate a quality assurance scheme meeting the requirements of the QSPSC of the HKQAA or BS 8500. The scheme shall cover all aspects of material supply, quality, batching, mixing transportation, and properties of the concrete. The

Contractor shall provide copies of the plant certificate with each mix submission. The Contractor shall advise any change of status of the plant(s) during the progress of the Works. The contractor shall be responsible for the performance of the Ready-mix Supplier. The Architect shall have the right to instruct the Contractor to change the supplier or to stop further use of ready-mixed concrete during the progress of the Works if the concrete has failed to comply with any of the requirements specified in the Specification.

Ready-mixed concrete shall comply with this Specification. All concrete shall be supplied and transported to the point of discharge from the mixer/agitator truck in accordance with the requirements of BS 8500-2: 2002 Section 12. Delivery tickets shall contain information in line with the particulars as required in Clause 3.8.12 and shall be completed and available before discharging concrete into the structure. Manually prepared records of batch composition are not acceptable. Where a ticket is marked 'non-conforming' a copy shall be passed to both the Contractor and the Architect within 24 hours of placing the concrete. All delivery tickets shall be retained by the Contractor for inspection throughout the duration of the contract.

All the constituents of each mix shall be measured and mixed at the manufacturer's depot. No extra water or other material shall be added after the concrete leaves the depot.

Contingency plans shall be in place before starting work in the event of supplies being interrupted during a pour due to a plant breakdown. Details of a suitable back-up plant/supplier should be submitted to the Architect for agreement.

2.8.6 Salts

The total amount of soluble chloride content in the concrete from the aggregates, water and any admixtures when tested to CS1 shall not exceed the values stated in Table 2.3 for the type of concrete involved.

Table 2.3

Type of Concrete	Maximum Total Chloride Content Expressed as Percentage of Chloride Ion by Weight of Cement
Prestressed Concrete. Steam-cured Structural Concrete	0.1
Concrete made with Sulphate Resisting Portland Cement	0.2
Reinforced Concrete	0.35
Un-reinforced Concrete	3.00

The total sulphate content of the concrete mix, expressed as SO_3 , shall not exceed 2.5% by mass of the binder (cement + SCM) in the mix unless it can be shown to the satisfaction of the Architect, with the nature of the concrete mix concerned in relation to the project to be applied, that a higher sulphate content (up to 4%) will not be detrimental to performance of the concrete. Concrete with sulphate content over 4% shall only be allowed to use for special purposes. The sulphate content shall be calculated as the total from the various constituents of the mix. The Contractor shall provide confirmation of compliance before any concrete is supplied to the Works.

Preliminary or routine testing may be required dependent on the choice of aggregate or admixture.

2.8.7 Alkali-Aggregate Reaction

Measures to control the occurrence of alkali-aggregate reaction (AAR) in concrete shall be submitted to the Architect for approval. In the absence of alternative proposals, such control shall be achieved by limiting the reactive alkali content of the concrete as described in Clause 2.8.8 below unless, in the opinion of the Architect, the concrete element will not be

subjected to moisture ingress throughout its design life. Attention is also drawn to PNAP 180.

The following particulars of the concrete mix shall be submitted by the Contractor to the Architect:

- (a) HOKLAS-endorsed test certificates not older than six months giving the results of test required in Clause 2.8.8: (a) to (f).
- (b) Calculation of the reactive alkali of the proposed mix; and
- (c) new HOKLAS-endorsed test certificates giving the results of tests required in Clause 2.8.8: (a) to (f) to 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.

2.8.8 Limit on Reactive Alkali

The reactive alkali of concrete expressed as the equivalent sodium oxide shall not exceed 3.0 kg per cubic metre of concrete. The equivalent sodium oxide content of the concrete shall be determined in accordance with the following steps:

- (a) The equivalent Na_2O shall be calculated by the expression

$$\text{Equivalent Na}_2\text{O} = A + B + C, \text{ where}$$

A is the sum of the acid-soluble alkalis (expressed as equivalent Na_2O) of cement, admixtures and water;

B is equal to 1/6 the total alkalis of PFA (expressed as equivalent Na_2O); and

C is equal to 0.76 times the chloride ion (Cl^-) of the aggregate.
- (b) The acid-soluble alkali content of the cement shall be determined in accordance with BS EN 196-2 and BS EN 196-5 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.
- (c) The acid-soluble alkali content of admixtures shall be determined in accordance with BS 1881: Part 124.
- (d) The acid-soluble alkali content of water shall be determined in accordance with American Public Health Association - *Standard Methods for the Examination of Water and Wastewater*, Sections 3500-K and 3500-Na.
- (e) The total alkali of the PFA shall be determined in accordance with BS EN 196-2 and BS EN 196-5 and shall be taken as the average of the latest 25 weekly determinations of equivalent sodium oxide plus twice the standard deviation of the results.
- (f) 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 812-117.

2.9 Steel Reinforcement

2.9.1 General

Each bundle of bent bars shall be clearly tagged with their schedule and mark numbers. Reinforcement should be free from mechanical damage.

2.9.2 Mill Certificates and Certificate of Origin

Every batch of steel reinforcement bars and fabric reinforcement delivered to the site shall be accompanied by certificate of origin and mill certificates that verify the mass and properties in accordance with CS2 and in compliance with the requirements stated in this Specification.

The Contractor shall satisfy the requirements of the BD by submitting the mill certificates and all relevant test reports, which shall be carried out by HOKLAS accredited laboratories, to the RSE for onward submission to the BD. These shall be accompanied by details of the manufacturer's identification marks rolled into each brand of bars supplied. For welded fabric reinforcement, the certificate shall also include the results of weld test.

2.9.3 Type of Reinforcement

(a) Bar reinforcement

When mild steel reinforcement is specified, such reinforcement shall be hot rolled plain bars with a characteristic strength of 250 MPa. When high yield deformed reinforcement is specified, such reinforcement shall be hot rolled deformed bars with a characteristic strength of 460 MPa. Both mild steel and high yield deformed reinforcement shall comply with BS 4449 and CS2.

(b) Fabric Reinforcement

Steel fabric for the reinforcement of concrete shall comply with BS 4483 and shall be factory-made machine-welded sheets manufactured from ribbed bars conforming to BS 4449 and CS2, or manufactured from wire conforming to BS 4482 for wrapping fabrics D49 and D98.

Steel fabric shall be delivered to Site in flat sheets.

Steel mesh for fire protection, which is required as per the Hong Kong Code of Practice for Fire Resisting Construction, to be included in reinforced concrete to reduce the risk of spalling shall be hot dip galvanized in accordance with BS EN ISO 1461 or stainless steel Grade 304.

2.9.4 Reinforcement Couplers

Where reinforcement couplers are used, the Contractor shall supply a type which is approved by the BD. Reinforcement couplers shall be used strictly in accordance with the manufacturer's written instructions. Samples of each type/diameter of couplers shall be tested in accordance with the requirements of the BD where specified or as directed by the Architect prior to the use in the Works. For bars in compression, the concrete cover to the sleeve shall not be less than that specified for normal reinforcement. For bars in tension, the mechanical coupler shall satisfy the following criteria (see also Clause 4.7.4):

- (a) when a representative gauge length assembly comprising reinforcement of the diameter, grade and profile to be used, and a coupler of precise type to be used, is tested in tension, the permanent elongation after loading to $0.6f_y$ shall not exceed 0.1mm; and
- (b) the coupled bar assembly tensile strength shall exceed 287.5 N/mm^2 for grade 250 bars, and 483 N/mm^2 for grade 460 bars.

Details of the selected couplers, including the source and suppliers, shall be submitted to the Architect for approval.

The Contractor shall provide suitable equipment on site for the Architect or his representative to inspect the installation workmanship of the couplers.

2.9.5 Spacers

Where spacers are required to maintain the concrete cover to the reinforcement these shall be of concrete or plastic and shall be as small as possible consistent with their purpose. The Contractor shall detail, supply and fix all spacers. The materials and workmanship shall be in accordance with Clause 7.3 of BS 8110: Part 1: 1985, and BS 7973 Parts 1 and 2. The Contractor shall ensure that the spacers have the required performance characteristics.

Where spacers have to carry heavy loads the Architect may require that plastic spacers shall not be used. The Contractor shall submit samples of concrete and plastic spacers to the Architect and obtain the Architect's approval in writing before starting steel fixing.

Concrete spacers shall contain maximum 10mm aggregate size and be of strength and durability equal to that of the concrete in which they are to be embedded. Where spacers require the use of tying wires to be fixed to reinforcement bars the wires shall be designed not to be exposed to the external unless they are made of stainless steel. Concrete spacer blocks shall not be used until they have an age of at least seven days.

Where concrete spacer blocks are required in visually exposed concrete they shall be made from materials matching those used in the surrounding concrete. The Contractor shall obtain the Architect's approval for the use of the spacer blocks.

Except otherwise specified in the Drawings, spacer bars shall be provided for multiple layers of reinforcement. For main bars of 25mm diameter or less, spacer bars shall be at 1m centres. For main bars greater than 25mm diameter spacer bars shall be at 2m centres. Spacer bars shall be of equal diameter to the largest bar in the layers being separated and in any case not less than 25mm diameter.

2.9.6 Tying Wire

Tying wire for fixing reinforcement shall be black annealed 16-gauge mild steel wire or equivalent. Tying wire for water-retaining structures, fair faced concrete and concrete exposed to the atmosphere shall be 18-gauge stainless steel wires.

2.9.7 Continuity Strips

Proprietary continuity strips can be used subject to agreement by the Architect.

2.10 Miscellaneous Materials

2.10.1 General

The Contractor shall submit full details of his proposed alternatives to the materials shown on the Drawings to the Architect for approval. Such alternatives shall be those that have already obtained approval from the BD, where applicable, unless the Contractor undertakes to apply for the necessary approval from the BD. Generally, such applications have to be undertaken by the Contractor without claims for costs and extension of time unless otherwise approved by the Architect.

Proprietary products shall be approved by the Architect in writing and used in accordance with the manufacturers' written instructions.

2.10.2 Waterstops

Waterstops (Waterbars) shall comply with Clause 4.1.10 and Section 4 of BS 8102: 1990.

Waterstops, where used, shall be as shown in the Drawings or as determined by the Contractor and approved by the Architect. They shall be jointed with purpose-made junction pieces. The Contractor shall submit shop drawings showing the sizes, types, isometric layout, jointing and support of all waterstops and obtain approval by the Architect in writing before starting installation. Intersection and change of direction waterstops shall be shop fabricated.

Hydrophilic waterstops shall be of a compound of polymer modified chloroprene rubber type. Hydrophilic strips of bentonite based material shall not be used unless otherwise approved by the Architect. The Contractor shall submit the technical data including its properties for the Architect's approval.

Hydrophilic strips shall be a minimum of 20mm x 10mm size and shall be coated with a "delay" coating to temporary protect from inclement weather and inhibit initial expansion due to moisture present in the fresh concrete.

See also Clause 3.15.4.

2.10.3 Cast-in and Drill-in Items for Other Trades

The Contractor shall submit details of all cast-in and drill-in items for other trades or Sub-contractors to the Architect for approval. The cast-in items should be shown on the Main Contractor's Combined Builder's Work Drawings, together with loading data & additional spreader reinforcement where necessary. Expansion or chemical anchors shall not be used except otherwise approved by the Architect. All cast-in and drill-in items shall be co-ordinated such that they do not clash with any reinforcing steel bars of the concrete structure.

Where approval from the BD is required for the use of such cast-in and drill-in items, e.g. fixings for curtain wall or cladding, the Contractor shall be responsible for the approval to be obtained in a timely manner to facilitate the cast-in and/or drill-in work. The cost and delay due to removal of any work without BD approval, or due to any remedial work required as a result of non-approved work shall be borne by the Contractor.

2.10.4 Bearings

Bearings and bearing strips shall be as specified on the Engineer's Drawings or of a similar approved type.

The Contractor shall submit the type, performance criteria, bearing detail data and test reports together with the design calculations to the Architect for approval in writing prior to any procurement.

2.10.5 Joint Fillers

Joint fillers shall be a proprietary type as specified in the Drawings or equivalent approved by the Architect and shall be placed strictly in accordance with the manufacturer's written instructions. Joint filler shall be firm, compressible, single-thickness, non-rotting and resistant to pests. Joint filler for joints in water retaining structures and water-resisting structures shall be non-absorbent.

Left in place joint filler in buildings shall comply with the specified fire rating.

2.10.6 Joint Sealants

Joint sealants shall be a proprietary type as specified in the Drawings or equivalent approved by the Architect and shall be used strictly in accordance with the manufacturer's written instructions. Primers must be compatible with the sealant to be used.

Poured joint sealing compound shall be hot poured rubber bitumen compound complying with BS EN 14188-1.

2.10.7 Permanent Steel Formwork

Permanent steel formwork may be used if approved by the Architect. The profiled steel sheeting shall be a proprietary product. It must be designed and used strictly in accordance with the manufacturer's written instructions.

2.10.8 Materials for Joints in Water Retaining Structures

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

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.

2.11 Storage of Materials

2.11.1 General

All materials shall be stored in a manner which is not detrimental to their use in the Works.

2.11.2 Reinforcement

Reinforcement bars shall be stored clear of the ground in designated safe load areas. The stored material should be protected from rain, water, corrosive materials and other materials that may be detrimental to their performance.

Different types and sizes of reinforcement shall be stored separately. Fabric reinforcement shall be stored horizontally.

2.11.3 Cement

All cements shall be stored in weatherproof structures having a raised dry floor or in a suitable silo.

Cement shall be used in the order that it is received on site. If for any reason the cement is not used for a considerable period, it shall be inspected before use. Any cement which,

upon inspection, is considered by the Architect to have been in any way affected by dampness or hydration or otherwise unsuitable for use will be condemned without further tests and shall be removed from the site.

Cement of different types shall not be mixed together.

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/equipment.

2.11.4 Aggregate

Aggregates shall be stored on hard paved self-draining areas or in approved hoppers or containers. Aggregate 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.

2.11.5 Admixtures, Curing Compounds and Materials for Joints

Admixtures, curing compounds and materials for joints shall be stored in watertight weatherproof and sealed containers or stores clearly marked to show the contents. All materials shall be stored in accordance with the manufacturers' written recommendations and shall not be used after the recommended shelf life has been expired.

2.12 Rejected Materials

All materials which are un-identifiable or do not comply with this Specification shall be removed from the site immediately at the Contractor's expense.

3 WORKMANSHIP AND CONSTRUCTION

3.1 Standard of Workmanship

The standard of workmanship shall be in accordance with this Specification, the relevant clauses of BS 8110 and all statutory requirements. Wherever differences occur, the more onerous requirement shall prevail.

3.2 Construction Loads and Contractor's Plant Effects to the Permanent Structures

During construction the Contractor shall ensure that the structure is not subjected to loads which will cause short-term or long-term distress and shall take account of the maturity of the concrete at the time of loading.

No loading in excess of the design loading shall be placed on any portion of the structure without the written permission of the Architect. If such permission is granted, all structural elements which are subjected to such loading other than the design load shall be strengthened and supported to the satisfaction of the Architect and any extra cost so incurred shall be borne by the Contractor.

Where the Contractor proposes to use the climbing tower cranes, or any type of plant which places any load on the structures, he must furnish full details and calculations of such plant with justification to the Architect for agreement before its erection and use. When required, the Contractor shall appoint an IRSE to prepare the calculations and detail method statements of the plant in working conditions, during raising and during dismantling operations.

The Contractor shall be responsible for making good and/or repair to the satisfaction of the Architect of any damages to the permanent structure which are caused by the erection/operation/dismantling of the plant and/or the excess construction loads.

If the Contractor desires to leave permanently any embeds in the structure for any purpose, he must furnish in writing the exact details of his proposals and such supports shall be subject to the agreement of the Architect.

Any temporary works that will have effects to the permanent works shall be designed and checked and certified by the Contractor's IRSE.

3.3 Construction and Preparation of Formwork

3.3.1 General

Design and construction of falsework and formwork shall be in accordance with BS 5975 and BS 8110: Part 1 where applicable.

Before construction of the formwork begins, the Contractor shall submit details of the formwork systems he proposes to use for all major structural works to the Architect and obtain the Architect's approval in writing before starting erection.

Formwork materials shall suit the method of construction to be used and the surface finish required for the final work where specified by the Architect.

The formwork shall be sufficiently tight to prevent loss of grout or mortar from the concrete. Formwork and falsework should be sufficiently rigid to ensure the final concrete structure complies with the specified tolerances.

The responsibility for the design, supply, construction, removal and safety of all falsework and formwork system (including but not limited to the falsework/formwork itself, stability of falsework during construction, checking the existing structure to support the falsework, back propping, removal of formwork and falsework etc) shall rest with the Contractor. The Contractor shall appoint an IRSE to check and certify the design prior to submission to the Architect. The qualification of the IRSE shall be subject to the approval by the Architect. The implementation of the actual arrangement on site against the design should be checked by TCP employed by the Contractor. The qualification of the TCP shall be subject to the approval by the Architect.

3.3.2 Holes, Inserts and Fixings

Approval for the size, type and position of any holes, cast-in inserts or fixings required by the Contractor or any Sub-Contractor (See Clause 2.10.3) shall be obtained before work proceeds.

Unless otherwise specified or approved, all holes through structural members shall be formed and all inserts and fixings cast in the concrete works at the time of concreting. No part of the concrete works shall be drilled or cut away without prior approval of the Architect.

Fixing lugs, lewis bolts, timber or breeze plugs or pads, floor clips and all other fixtures must comply with the architectural requirements and must be of a type and size to avoid any weakening of the structural concrete and/or chemical contamination thereof.

Any fixture to be inserted into the structural concrete by means of explosive is not allowed.

Any clashes between holes, cast-in items and reinforcement shall be resolved before any concrete is placed. Reinforcement bars in the main structure should not be dislocated to make way for cast-in items unless approved by the Architect.

The Contractor shall clear out block out items after concreting.

3.3.3 Release Agents

Release agents shall be materials marketed as such and shall be of one of the following types approved by the Architect:

- (a) cream emulsion
- (b) neat oil with surfactant added
- (c) chemical release agent

All release agents used shall be non-staining, non-injurious to the finished concrete and shall not be adversely affected by the weather.

Release agents shall be stored and used strictly in accordance with the manufacturer's written instructions. Architect's approval shall be obtained for the compatibility of the release agent with the surface finishes.

3.3.4 Formwork Ties

Through-ties may be used to support vertical faces of formwork other than in water-resisting construction or as agreed with the Architect.

No metal part of any device for maintaining formwork in the correct location shall remain permanently within the specified concrete cover to the reinforcement.

The Contractor shall make good any holes left exposed to view in the faces of the concrete to the agreement of the Architect.

In water-resisting construction, methods of fixing formwork which result in holes through the concrete section when formwork is removed shall not be used.

In water-resisting construction, ties used shall be of a type to maintain water resistance of the construction.

3.3.5 Cleaning of Forms

All rubbish shall be removed from the interior of the forms before concrete is placed. The formwork in contact with the concrete should be cleaned and treated with an approved release agent. In the case of deep sections a temporary opening shall be left at the base to enable such cleansing to be adequately completed and avoid ponding prior to concreting.

3.3.6 Pre-Cambers

All formwork for suspended beams and slabs shall be constructed so that the upward cambers as shown on the Drawings exist immediately before striking. If camber is not specified on the Drawings, the following guidelines are provided:

- (a) 0.15% of span length at the centre of span, for span length up to 10m.
- (b) The sum of 0.15% of the first 10m plus 0.30% of the rest of span length for span length over 10m.
- (c) 0.35% of span length at the free end of a cantilever span.

The Contractor shall check the prescribed precambers are compatible with his chosen method of construction and time to striking of formwork and falsework. It shall remain the Contractor's responsibility to ensure the complete structure is within specified tolerances, and suitable to receive the work of following trades and Sub-contractors.

3.3.7 Stiffness of Formwork Panels

Formwork panels shall be stiff enough to prevent damage to the concrete surface caused by excessive movements of the panel during vibration of the concrete.

3.3.8 Repair of Formwork

Damaged formwork shall not be re-used if in the opinion of the Architect that the making good would impair the surface appearance of the concrete.

3.3.9 Design of Formwork to Suit Striking Method

The side formwork should be so designed and arranged that it can be removed while the soffit form can be retained in position, properly supported on props, until the concrete has achieved the required maturity.

The Contractor shall submit to the Architect for approval their method statement for removal of formwork.

3.3.10 Sealers on Timber Surfaces

Where their use has been specified or approved, sealers shall be applied to surfaces which are dry and free from dirt, grease or other impurities. Before a surface is sealed, it shall be

sanded to remove any protrusions or to smooth any rough areas. Any holes or indentations shall be stopped with waterproof filler. The manufacturer's instructions regarding the method of applying the sealer shall be followed exactly and the work shall be done by a skilled painter.

Whether or not the surface of the formwork in contact with the concrete is sealed all edges and joints to plywood or other timber, including the edges of any holes drilled through it, shall be sealed.

3.3.11 Sloping Forms

When concrete is to be placed to an angle steeper than 15° from the horizontal top forms shall be used to enable the concrete to be properly compacted.

3.3.12 Curved or Domed Concrete Surfaces

Where curved or domed surfaces are specified, the formwork shall be curved or domed accordingly. The alternative of replacing a curved or domed concrete surface with a series of small connecting planar surfaces will not be permitted unless the concrete exposed surface will be covered by tiles and the Contractor has demonstrated to the satisfaction of the Architect that the irregularities on the concrete surfaces due to such alternative will not affect the final smoothness of the tiled surface, and the Architect's written approval is given.

3.4 Falsework

3.4.1 General

The Contractor shall be responsible for the design, supply, construction, removal and safety of the falsework. See also Clause 3.3.1.

The falsework shall have sufficient stiffness to prevent excessive deformation, to support the formwork, cast elements, and any imposed loads before the poured concrete reaches the required strength. Not less than 3 weeks before construction of the falsework begins, the Contractor shall submit method statements, calculations and details of the falsework systems he proposes to use for all main structural construction to the Architect and obtain the Architect's approval in writing before starting falsework erection. The method statements shall include layout drawings of formwork and falsework, details of the props, e.g. their load capacities, connection and bracing details, assumed rates of concreting, and removal sequence.

Where structural concrete relies on permanent or temporary support from the existing structure or ground, the Contractor shall ensure that the support is adequate for such purposes.

3.4.2 Formwork Props

Formwork props are part of the falsework required for the support of the formwork cast elements, and imposed loads. The props shall remain in place for the minimum striking period established under Clause 3.10.

In calculating the load capacities of the props, the Contractor shall take account of their slenderness.

All formwork props shall have base plates for safely spreading their load to the supporting member without damage.

3.4.3 Stability of Falsework during Construction

The Contractor shall be responsible for the stability of all the falsework systems, and shall provide adequate lateral supports and bracings to assist the falsework in resisting all concrete and imposed loads during construction.

No bracing of the falsework system shall be removed prior to the minimum striking period established under Clause 3.10.

3.4.4 Safe Access for Concreting

The Contractor shall include in his method statement details of his proposed access to, and working platforms at concreting work faces where the height of the platform exceeds 2m above the local general level.

3.4.5 Back Propping

The Contractor shall check that the maximum loads taken by the falsework system can be safely carried by the supporting structure. If back propping is required to distribute the loads between two or more consecutive floors, the Contractor shall obtain the Architect's prior approval in writing to his proposals for back prop layout, and sequence for installation and removal.

3.4.6 Removal of Formwork and Falsework

The Contractor shall be responsible for the safe timing, sequence and manner of removal of any falsework or formwork.

3.5 Construction Joints

3.5.1 General

Where construction joints are not shown on the Drawings the Contractor shall submit his proposed construction joint positions with method statement of the joint preparation and concreting sequence to the Architect for approval before work starts.

3.5.2 Preparation of Construction Joints

Prior to the Works commencing on site, the Contractor shall obtain the Architect's approval for proposals of forming and preparing construction joints.

All construction joints other than horizontal joints shall be formed with proper stop-boards which shall be fixed vertically unless otherwise directed.

At construction joints, all laitance and honeycombed concrete shall be removed from the contact face to expose the coarse aggregate before the adjacent section is concreted. Where difficulty of access makes the removal of laitance impossible, the means of producing a roughened joint face of properly compacted concrete shall be approved.

When work is resumed at a construction joint the contact face shall be clean and saturated with water but with no free water present at the surface. The fresh concrete shall be placed directly against it. No grout or mortar shall be used.

The use of surface concrete retarders and bonding agents at construction joints shall be subject to approval in writing of the Architect.

3.5.3 Spacing of Construction Joints

The spacing of construction joints other than those in water-resisting construction shall comply with the requirements stated in Table 3.1 unless otherwise shown on the Drawings or approved:

Table 3.1

Construction	Maximum Area (m ²)	Maximum Length (m)
Slabs with major restraint at both ends	100	13
Slabs with major restraint at one end only	250	20
Slabs with little restraint in any direction	500	30
Walls	40	10

The Contractor shall propose the joint layout with design justification for the additional anti-crack reinforcement required if the above requirement is exceeded. Attention shall

be drawn to the possible thermal/shrinkage induced cracking due to massive pour. For areas of water-resisting construction, refer to Clause 3.15.

3.5.4 Shrinkage Strip

Where shrinkage strip is specified on the Drawings, construction joints shall be properly formed with stop-boards. All reinforcement across the shrinkage strip should be discontinued and lapped with full bond length. Prior to commencement of concreting the infill area, the joint faces shall be properly cleaned and roughened.

The Contractor shall programme his work to allow for the specified shrinkage strip, and follow the sequence and timing for infilling the shrinkage strip area as directed in the Drawings or by the Architect.

Where shrinkage strip is required in external environment, waterstop shall be provided in accordance with Clause 3.15.4.

3.5.5 Construction of Cantilevered Reinforced Concrete Structures

All cantilevered structures should be cast monolithically with the direct supporting members. Construction joints should not be located along the external edge of the supporting members. In case this is inevitable, an alternative construction method must be submitted to the Architect for approval prior to the commencement of Works.

3.6 Movement Joints

Concrete shall not be placed on both sides of a movement joint at the same time unless otherwise approved. Joint filler forming the gap at a movement joint should be firmly fixed to the first-placed concrete. If more than one strip is used, the ends should be butted closely together and taped to prevent grout leakage thus preventing the closure of the joint.

A method statement for forming movement joints shall be submitted to the Architect for approval. Details of placing the joint material and bearing pads, if applicable, shall be included in the method statement.

The permanent sealing of joints shall be carried out as late as practical and preferably in cool weather. Excess joint sealant shall be removed by using a purpose made finishing tool such that the finish surface of the sealant is between 4mm and 6mm set back from the face of the concrete.

If required by the Architect, samples of joint filler shall be tested to determine the disintegration and shrinkage, the recovery value and reduction in mass and the extrusion.

Unless otherwise specified in the drawings, dowel bars shall be 25mm diameter Grade 250 plain round steel bars complying with CS2 at 300mm spacing. Dowel bars shall be straight and sawn square at both ends with all burrs removed. The bar length shall be 650mm long. 300mm cast in one side and the other sides slotted into a preformed PVC tight fitting dowel sleeve with a nominal wall thickness not exceeding 1.5 mm.

3.7 Reinforcement Handling

3.7.1 Reinforcement Cutting and Bending

The Contractor shall prepare his own bending schedule for cutting and bending reinforcement bars in accordance with the reinforcement detail Drawings.

All reinforcement shall be bent only to the details shown on the Drawings and in compliance with BS 8666 and BS 8110: Part 1: 1985, Clause 7.2 unless otherwise stated or approved by the Architect in writing. Tolerance on cutting and bending reinforcement shall comply with BS 8666.

Reinforcement should not be bent or straightened in a manner which will damage the material. Grade 460 bars should not be re-bent or straightened without the Architect's approval. Reinforcement shall not be heated.

Where not specifically detailed in the Drawings, the laps of reinforcement shall be staggered so that laps do not occur in a band.

Each bundle of bars shall be clearly tagged with their schedule and mark numbers.

3.7.2 Reinforcement Fixing

Reinforcement fixing shall not start until satisfactory testing of representative batches has been completed. Attention is drawn to PNAP 122 and 221 in this regard.

All reinforcement shall be fixed in position in accordance with the reinforcement detail Drawings and reinforcement schedules. Any alterations to the reinforcement shall be carried out only with the agreement of the Architect.

Steel reinforcement shall be clean and free from corrosive pitting, paint, oil, grease, spilt concrete or grout, adhering earth or loose rust, rust scale, loose mill scale etc. at the time of fixing in position and concreting.

All laps of fabric and all intersections of bars shall be securely connected with tying wire or by an alternative method approved by the Architect.

Welding of reinforcement is not permitted without the Architect's agreement in writing. Where welding is allowed, it should be carried out in compliance with Clause 10.4.6 of the HKCC and BS 7123. Welding procedures and welder qualifications shall be subject to the agreement of the Architect.

Except otherwise specified the concrete cover to reinforcement shall be the minimum recommended in Table 4.2 of the HKCC, and the tolerances for fixing reinforcement should be as follows:

- actual concrete cover not less than the specified covers minus 5 mm.

For reinforcement located relative to only one face of a member, the actual concrete cover must not exceed the specified cover plus:

- 5 mm on bars up to and including 12 mm diameter;
- 10 mm on bars over 12 mm up to and including 25 mm diameter; or
- 15 mm on bars over 25 mm diameter.

With the exception of using stainless steel wires in spacer blocks, no metal part of any device used for connecting reinforcement bars or for maintaining reinforcement in the correct position shall be remained within the specified minimum concrete cover to the reinforcement.

The Contractor shall supply and fix all chairs required to maintain reinforcement bars in the correct positions. The Contractor shall obtain agreement to the type, size and spacing of chairs in advance of commencing the area of work.

See Clause 3.8.5 for attendance by steel fixer during concreting.

3.7.3 Rust Staining

Concrete surfaces which will be exposed to view in the finished works shall be protected from staining due to rusting of projecting reinforcement either by coating the reinforcement with cement grout or by another method approved in writing by the Architect.

3.7.4 Safe Access for Steel fixing

The Contractor shall include in his method statement details of his proposed access to, and working platforms at, steel-fixing work faces where the height of the platform exceeds 2m above the local general level.

3.7.5 Projecting Reinforcement

All reinforcement ends left projecting from cast concrete shall be free of release agents and shall be protected against damage and corrosion by polythene sleeves tied to the bars or coating the bars with cement slurry.

3.8 Concreting

3.8.1 Method Statement

The Contractor shall submit a method statement for concreting operations of the Contract to the Architect for approval. The method statement shall cover comprehensively all the different arrangements of concreting at different locations. Details of each arrangement shall include the following:

- (a) volume of concrete delivered and placed per hour;
- (b) tools and equipment utilized;
- (c) mode of placing, e.g. by skip, or pumping etc;
- (d) number of persons in the concreting team;
- (e) means of safe working at height; and
- (f) contingency plans for unexpected situations, e.g. rain, disruption of concrete supply, accidents, etc.

If pumping concrete is to be used, the method statement shall also include:

- (g) general arrangement and methods of supporting pipelines; and
- (h) procedure for charging and emptying of pipelines.

If pumping concrete is to be used, the inside diameter of the pipes and hoses shall not be less than three times the maximum size of the aggregate. Aluminium pipes shall not be used. Extra strong couplings shall be used on vertical runs and on sections which are not easily accessible.

Concrete pumps shall be operated and maintained in accordance with the manufacturer's written recommendations and shall produce a continuous stream of concrete without air pockets. The pumps and pipelines shall be maintained in a clean condition. Pipelines shall be lubricated by passing cement grout through the pipeline before the Permanent Works concrete is pumped. This initial lubricating grout shall not be placed in the Permanent Works.

3.8.2 Notice of Concreting

Before each concrete pour, the Contractor shall give an advance notice of at least one day to the Architect so that an inspection of the concreting may be made at his discretion. Such notice shall provide details of the concreting operation including:

- (a) the date and time for the Architect or his representative to inspect the formwork and fixed reinforcement;
- (b) the location of concreting;
- (c) the elements to be concreted;
- (d) the volume of concrete to be poured;
- (e) grade of concrete to be poured; and
- (f) date and starting time and expected completion time of the operation.

No concreting shall be commenced until the Architect or his representative has had an opportunity to inspect the formwork and any fixed reinforcement and given his written approval to concreting.

3.8.3 Attendance at Concrete Unloading Area

During each delivery of concrete to site, a suitably trained concrete technician employed by the Contractor shall stand by at the unloading area for the concrete trucks and attend to the following:

- (a) to take concrete temperature;
- (b) to carry out slump test;

- (c) to decide on the acceptability of the concrete, record the concrete volume arrived (both accepted and rejected), collect the delivery tickets if accepted; and
- (d) to do sampling and concrete cubes.

The technician shall be familiar with the acceptance criteria for (a) to (d) above. The technician in charge shall be given the authority to reject unacceptable concrete and report to the Contractor's site agent any anomaly regarding the concrete or delivery and he shall also be responsible for collecting and keeping all the above records and test reports.

Concrete temperature shall be taken with approved thermometers prior to unloading of the concrete on site, at least once every hour or as directed. Temperature of the concrete at placing shall not exceed 30°C.

All delivery record slips for ready-mixed concrete shall be retained by the Contractor for inspection throughout the duration of the Contract.

3.8.4 Transporting Concrete On Site

Runs or gangways for concrete transports and main runs for foot traffic shall not be supported or allowed to bear on the fixed reinforcement for permanent works. Concrete shall be deposited as near to its final position as practical to minimize re-handling or flowing.

Concrete shall be transported from the concrete unloading area to the place of concreting as quickly as possible by methods which will prevent segregation or loss of ingredients including water.

3.8.5 Placing Concrete

Concrete shall be placed continuously up to construction joints while it is still sufficiently plastic for adequate compaction. Concrete shall be rejected if its workability test result fails to comply with the specified requirements in this Specification when tested according to either Clauses 4.6.1 and 4.6.2 or Clause 4.6.6 or Clauses 5.4.8(a) and (b) subject to the concrete mix, or if it is not placed within two hours of the introduction of water to the cement and aggregate.

Concrete shall be compacted in layers not exceeding 0.6m thick during placement and compaction of each layer shall be completed before the next layer is placed. Care should be taken to ensure that successive layers are well worked together.

At all times when concrete is being placed, a competent steel fixer shall be in continuous attendance. He shall inspect the reinforcement in advance of the concreting movement, and adjust or correct the position of any reinforcement which may have been displaced or found to be loose.

Concrete shall not be allowed to fall freely for more than 2m. Chutes should be used instead.

Where permanent formwork is incorporated in the structure extra care is required, as full compaction of the concrete cannot be checked after the formwork is removed.

Arrangements for premature stoppage of a pour shall be agreed and in place before work starts. Should premature stoppage of a pour occur, the Contractor shall agree with the Architect the extent and timing of any necessary remedial work before resumption of placing. Should this happen during concrete placing, it should be recorded by the Contractor and the Architect should be notified. Coring test may be required as directed by the Architect, to verify the quality of the concrete bonding interface.

Concrete shall not be placed under heavy rainfall unless adequate tented protection is provided or otherwise agreed by the Architect. Any concrete that has been damaged, contaminated or diluted by rainfall shall be removed from the Works.

3.8.6 Placing Concrete on Rock

Rock surface upon which structural concrete is to be placed shall be free from oil, mud, standing water (except concrete is placed by tremie) and any kind of foreign matters. Loose, shattered or unsound rock fragments shall be removed. The surface shall be inspected and

approved by the Architect before blinding concrete is placed. Except otherwise specified in the Drawings the blinding concrete shall be of Grade 10P and 50mm thick minimum and shall be cast in bays with vertical joints properly formed. Immediately before placing the blinding concrete, the rock surface shall be thoroughly wetted so that water is not absorbed from the blinding concrete.

3.8.7 Placing Concrete for Formed Finish

Concrete shall be placed in one continuous operation rising uniformly in the formwork at a rate not less than 2m per hour. The concrete shall not be handled in any manner that may cause segregation or cold joints.

Concrete shall not be placed directly against a vertical form face but shall be caused to flow to this surface during the compaction process. Care shall be taken to avoid the form face being splashed with mortar during the placing operation.

3.8.8 Compaction

All structural concrete except self compacting shall be fully compacted by mechanical vibrators of an appropriate type and size to avoid cold joints and honeycombing and to minimize segregation, excessive blemishes or other defects in the hardened concrete. Concrete shall be thoroughly compacted in its final position within 30 minutes of discharge from the mixer.

The Contractor shall submit details of the type, size and number of vibrators to be used in the Works. Whenever concrete is being vibrated, at least one spare vibrator of each type in use shall be available in case of breakdown.

Compaction shall start as soon as there is sufficient concrete within the formwork to immerse the vibrator and vibration shall continue during the placing operation so that at no time shall there be a large volume of un-compacted concrete in the formwork. Immersion vibrators shall be fully inserted into the concrete at points of application and not exceeding 0.5m apart and shall be withdrawn slowly to prevent the formation of voids. Immersion vibrators shall avoid contact with the formwork, the reinforcement or any embedded fixtures.

Over vibration, causing segregation, surface laitance or leakage through formwork, shall be avoided.

Kicker sections of walls, columns etc. shall be cast monolithically with the base slab and compacted in such a way that their strength and other characteristics are at least equal to those specified for the whole member.

At areas with very congested reinforcement, trial panel may be required as directed by the Architect to ensure that the quality of hardened concrete can be attained.

3.8.9 Re-vibration

Where for any reasons, concreting cannot be carried out without interruption, care shall be taken that vibration of new concrete, in contact with that vibrated before the break, is done within 30 minutes of the stoppage unless in the opinion of the Architect, the concrete already placed is sufficiently workable and responds to the action of internal vibrator. If this cannot be arranged, the old concrete must be left to harden and undisturbed for at least 24 hours before the new concrete is poured, and the joint treated as a normal construction joint, as specified. The cost of any additional works caused by these stoppages shall be borne by the Contractor.

3.8.10 External Vibrators

External vibrators shall not be used without the approval of the Architect in writing.

3.8.11 Cleaning

All equipment used for mixing, transporting, placing and compacting concrete shall be thoroughly cleaned before changing from one type of aggregate or cement to another, and when the respective operation using the equipment is completed or before the grout/concrete attached to the equipment hardens.

3.8.12 Records of Placing

The Contractor shall submit weekly to the Architect a complete record of the concrete placing done showing the time and date of concreting, the locations and types of structural member cast.

The Contractor shall keep on site a record containing the following particulars:

- (a) Date and time of arrival of the concrete trucks;
- (b) Time of batching and quantity of water added at Site if any;
- (c) Registration number of each truck and name of depot, serial number of delivery ticket;
- (d) Time when concrete was placed;
- (e) Grade of concrete and quantity;
- (f) Temperature of concrete when placed;
- (g) Accurate description of the location of concrete placement;
- (h) Reference marks of any test cubes taken from this delivery;
- (i) The slump; and
- (j) Type, name and quantity of admixture if used.

The record book shall be available for inspection by the Architect or his representative at all times.

3.8.13 Curing

All surfaces of structural concrete shall be protected from loss of moisture by suitable curing process immediately after compaction and the curing period which, for concrete using PC only, shall be at a minimum the first four days after casting. The minimum curing period of six days is required for concrete containing PFA. Formwork left in position can be regarded as protection for the surfaces with which it is in contact.

For finished concrete other than water-resisting construction, the curing shall be provided by one of the following means:

- (a) A membrane, formed by an approved proprietary liquid curing compound by using a mechanical sprayer with low-pressure spray at the rate recommended by the manufacturer, on the horizontal surfaces immediately after finishing the concrete and on vertical surfaces immediately after removing the formwork until a continuous visible covering is achieved.
- (b) Cover the finished concrete completely, after thoroughly wetting, with 0.125mm thick impermeable polyethylene sheeting raised approximately 50mm over the surface.
- (c) Cover the finished concrete completely with a layer of fine aggregate at least 25mm thick or Hessian, sacking, canvas or similar absorbent material. Such covering layer shall be kept constantly wet during the curing period.

For water-resisting structures, the curing shall be provided by one of the following means:

- (d) Upon completion of the finishing process, all exposed surfaces shall be covered with 0.125mm thick impermeable polyethylene sheeting until such time as the concrete has hardened sufficiently to permit water curing. Water curing shall be effected whenever possible by the continuous spraying of cool water or by ponding immediately after the sheeting is removed for a period of two days. Particular care shall be taken to avoid thermal shock at the surface of the concrete caused by the intermittent application of large quantities of cool water. Thereafter, spraying of cool water shall continue or be substituted by the aforesaid method (b) until the concrete has reached the age of seven days.
- (e) Formwork to vertical elements shall be kept moistened by water sprays as soon as the concrete has hardened sufficiently and until the formwork is removed, then the aforesaid curing method (b) shall be adopted until the concrete has reached the age of seven days.

All the covering materials shall be lapped and securely held in position in such a manner that the concrete under curing will not be damaged.

Before commencing concreting the Contractor shall obtain prior approval of his proposals for concrete curing.

3.8.14 Temporary Protection for Fresh Concrete

After the compaction, the fresh concrete should be protected from vibration and impact which may disrupt the concrete and interfere with its bond to the reinforcement.

3.8.15 Pouring of Concrete against Walls of Adjoining Building

Concrete can only be poured against adjoining building walls on the condition, complying with PNAP 81, that the process will not cause damage to the property and injury to person subject to the written approval of the Architect.

Independent shuttering shall be provided for pouring concrete against the wall of the adjoining building to avert excessive wet concrete and tamping load so imposed.

3.9 Special Requirements Regarding Concrete Temperature

3.9.1 General

Under an ambient temperature above 25°C, any formwork made of metal, concrete or other material of high thermal capacity shall be cooled with water before concrete is placed.

The concrete temperature at the time of placing shall not be more than 30°C. The Contractor shall have an approved thermometer at the concreting location for checking the concrete temperature at any time.

The Contractor shall employ effective means such as pre-cooling of aggregate and mixing water, as necessary, to maintain the temperature of the concrete below 30°C prior to placing. The Contractor shall liaise with the batching plant to control the concrete temperature prior to and during the concreting operation.

3.9.2 Concreting in Hot Weather or High Wind

For exposed concrete surfaces in high sun temperature or strong drying wind conditions the Contractor shall provide shield to the fresh concrete during the curing period, and this shield shall be placed in position no later than half an hour after final tamping. If the surface exhibits cracking while the concrete is still plastic, it shall be re-tamped to close the cracks.

3.9.3 Heat of Hydration

The peak temperature of the concrete shall not exceed 70°C at any point of a cast section, unless it can be shown to and approved by the Architect that with the nature of the construction and the concrete mix concerned, a higher temperature will not be detrimental to the concrete performance. In this case, this limit may be relaxed up to 85°C. When the concrete temperature exceeds 70°C, the Contractor shall inform the Architect and investigate the case.

The temperature difference between any two points within 1m apart in a cast section shall not exceed 25°C. Cooling and/or insulation of the concrete shall be carried out as necessary to maintain the above conditions.

Before casting sections greater than 1.5m thick, or concrete is to be placed in a large volume pour, and if a rich concrete is used, consideration shall be given to the concrete temperature rise above ambient and to reduce the risk of early thermal cracking. The Contractor shall demonstrate by means of thermocouples in representative trial panels that the specified peak temperature and temperature difference are not exceeded. The Contractor shall propose the size and layout of the representative panel, the mix design, and number and arrangement of thermocouples for the approval of the Architect in writing before the demonstration.

Where a risk of thermal cracking is identified, the location of temperature monitoring apparatus and interpretation of the temperatures recorded shall be agreed with the Architect prior to installation.

3.9.4 Concreting in Cold Weather

When the ambient temperature is 5°C or below, or is likely to drop in that direction, the Contractor shall not carry out any concreting without prior approval from the Architect.

If concreting at ambient temperature below 5°C is anticipated, the Contractor shall submit a method statement for concreting in cold weather to the Architect for approval. Details of the method statement shall include the following:

- (a) insulating the concreted works from the ambience to keep the minimum temperature at any point of the concrete section above 5°C;
- (b) maintaining the temperature of formwork to a minimum of 5°C prior to start of concreting;
- (c) temperature monitoring measures for the minimum and maximum temperatures in the poured concrete;
- (d) measures to keep the difference between maximum and minimum temperatures within 25°C; and
- (e) remedial work proposal for non-compliance of the above requirements.

3.10 Striking of Formwork

3.10.1 General

Before any formwork is removed the Contractor shall ensure that the concrete has attained sufficient strength to support its own weight and any construction loads, without short-term or long-term distress. The structure shall not be distorted, damaged or overloaded in any way by the removal of the formwork.

The Contractor shall be responsible for the safe timing, sequences and manner of removal of any falsework or formwork. Formwork shall be removed carefully to avoid damaging the concrete surface. Any damage so caused shall be made good by the Contractor to the acceptance of the Architect.

3.10.2 Method Statement

The Contractor shall submit method statements for removing formwork and falsework to the Architect for approval. These method statements shall be compatible with the requirements of the designs and method statements for the formwork and falsework.

3.10.3 Minimum Striking Period

The minimum time before removing formwork shall be determined from either (A) or (B) below unless otherwise specified. The Architect may approve earlier striking of forms (but not props) if the Contractor can show that this can be done without damage to the concrete.

When SCM are used and the surface temperature is less than 16°C the minimum striking time shall be determined by (B).

- (A) The minimum striking times shall be as listed in Table 3.2 (for concrete without SCM) and Table 3.3 (for concrete with SCM and having the surface temperature $\geq 16^{\circ}\text{C}$). The Contractor's method of measuring the surface temperature of the concrete shall obtain prior approval from the Architect.

The periods specified for striking of soffit formwork and props at 7°C shall be increased by half a day for each day on which the minimum concrete temperature is between 2°C and 7°C. Any day on which the minimum concrete temperature falls below 2°C shall not be counted.

Table 3.2: For Concrete without SCM

Location	Minimum Striking Time	
	Surface Temperature of Concrete T	
	T ≥ 16°C	16°C > T ≥ 7°C
Beam sides, walls and columns	12 hours	12 hours
Slab soffits (formwork props undisturbed)	4 days	7 days
Formwork props to slabs	10 days	14 days
Beams soffits (formwork props undisturbed)	7 days	14 days
Formwork props to beams (Except cantilever)	14 days	21 days
Formwork props to cantilever, hanger walls and transfer structures	28 days	28 days

Table 3.3: For Concrete with SCM and having the surface temperature ≥ 16°C

Location	Minimum Striking Time
Beam sides, walls and columns	15 hours
Slab soffits (formwork props undisturbed)	5 days
Formwork props to slabs	11 Days
Beams soffits (formwork props undisturbed)	8 days
Formwork props to beams (Except cantilever)	15 days
Formwork props to cantilever, hanger walls and transfer structures	29 days

- (B) The Contractor may determine the striking time from the strength of the concrete. The forms and/or formwork props to a structural member may be removed when the strengths of two concrete cubes made from a batch used in the member and cured and stored under the same conditions as the member both exceed 10 N/mm² or twice the stress to which the concrete will be subjected, whichever is the greater, provided that such earlier striking will not result in unacceptable deflections due to shrinkage, creep, etc.

Permission to carry out this procedure will be withdrawn if the Architect is not satisfied that the strength of the cubes is representative of the strength of the poured concrete.

Notwithstanding the above, formwork props shall remain in position for at least 3 days.

3.11 Treatment of Cast Concrete

Unless shown in the Drawings or directed by the Architect, no treatment of any kind other than that required for curing shall be applied to the concrete after removal of the forms until it has been inspected by the Architect.

3.12 Concrete Finishes

3.12.1 General

Where no finish is indicated on the Drawings a smooth dense surface free of voids and honeycombing is required.

The Contractor shall check and follow the Architectural specification and drawings for the type/quality of surface finish required for various elements. The Contractor shall pay particular attention, where fair face concrete, rendering, painting or other surface applications are required by the Architect.

Where a particular type of finish is required on specific concrete surfaces it will be indicated on the Drawings. The reference to finishes shall have the meanings described in Clauses 3.12.2 and 3.12.3.

3.12.2 Formed Concrete Finishes

Type 1F

Form material shall be good quality plywood or similar and shall have uniform panels and fixings arranged in a regular pattern.

Small surface blemishes caused by entrapped air or water may be expected, but the surface shall be free from voids, honeycombing or other large blemishes. The concrete surface shall be the finish except that, if required by the Architect, defects such as fins and other minor blemishes shall be made good by an approved method.

Type 2F

Form faces shall be of an impervious material such as plastic-laminate-faced plywood, GRP or steel. Form panels shall be as large as practicable and arranged in an approved regular pattern. The finish shall be smooth without significant blemishes or discolouration. No making good will be permitted except with approval. Internal form ties and spacers for maintaining concrete cover will not normally be permitted.

Type 3F

Formwork type 3F is to be generally as specified for 2F but extra care shall be taken to ensure that the concrete surface has no blemishes or discolouration and meets with the Architect's requirement.

The surface of each prefabricated formwork panel is to be inspected for marks, indentation, holes or blemishes, which are either to be made good to the Architect's satisfaction, or the panel shall be withdrawn from use as 3F formwork.

When concrete is placed, the surfaces of the panels are not to be splashed with concrete or grout and the formwork joints shall be grout tight.

3.12.3 Unformed Concrete Finishes

Type 1U The concrete shall be uniformly levelled and tamped.

Type 2U The concrete shall be uniformly levelled and tamped, and subsequently wood floated by hand to produce a uniform surface.

Type 3U The concrete shall be uniformly levelled, tamped and floated. When sufficiently hard it shall be steel floated by hand or machine to produce a dense, smooth, uniform surface free from tool marks.

Type 4U Except otherwise shown on the Drawings, the finish for vehicular ramps shall be of Type 2U finish on an extra concrete layer of 15mm thick and same grade of the slab on top of the ramp cast monolithically with the slab with anti-skid grooves of 10mm (W) x 15mm (D) at 100mm centres formed evenly across the slab in one direction at right angles to the longitudinal axis of the vehicular ramps.

3.13 Quality of Exposed Concrete Surface

3.13.1 Appearance

Any finished work which the Architect judges to be inferior in any respect to a standard, or to be unacceptably different in appearance from other parts of the works already constructed, or which is subsequently stained or damaged, will be classed as defective work.

3.13.2 Protection

Surfaces which will be exposed to view without rendering in the finished works shall be protected from spillage, stains, discoloration and any other damage at all time.

3.14 Trial Panels

In order to ensure that the specified formed finishes can be achieved by the method of construction and formwork proposed, and to provide a standard by which the finishes in the Works can be assessed, trial panels shall be cast on site as directed by the Architect. These panels shall be approved before similar construction is started for the Works.

The trial panels shall be cast with concrete using the materials, plant, and concrete mix and methods of placing and compaction proposed for the Works. They shall be at least of storey height and 1m wide.

They shall be of similar thickness and similarly reinforced as the elements they represent, and shall incorporate all features which may contribute to their final appearance, i.e.:

- horizontal and vertical construction joints;
- horizontal and vertical panel joints;
- arises and chamfers;
- tie bolts or other fixing devices;
- means of maintaining concrete cover to reinforcement;
- release agent; and
- any other features.

3.15 Water-resisting Construction

3.15.1 Responsibility

The structural elements that would be in direct contact with soil or water have been designed in accordance with the HKCC, and have been checked such that the maximum crack widths should not be more than the values as stated in Table 7.1 of the HKCC. To achieve water-resisting construction, due considerations shall be made in respect of construction method, concrete mix, inserts and false work through the structure, joints and method of curing etc. The Contractor should refer to the Architects drawings and specification for the areas of water-resisting construction and the performance requirements.

The Contractor is responsible for planning, detailing and controlling the construction works, so that they achieve the water-resisting performance required by the contract. If a warranty is required in the Contract, the Contractor shall prepare and submit to the Architect a) the drawings and method statements to show the details of all construction joints, pouring sequence, curing methods etc.; and b) the quality plan ensuring the provision of adequate quality control measures. The Contractor shall check and confirm to the Architect in writing, before commencing a particular area of the Works, that they are satisfied with such proposal that the elements will achieve the water-resistance requirement. The Contractor's particular attention is drawn to the recommendations described in BS 8007 and BS 8102 for monolithic structural protection.

The Contractors' engineering and QC staff shall check and supervise the steel fixers, paying particular attention to good detailing practices and staggering of laps to prevent local stress

concentrations which may cause cracking. The Contractor shall also submit to the Architect before starting work written confirmation from the waterproofing system supplier that the proposed concrete mix, placing methods, release agents, curing compounds, movement joint details, surface finishes, reinforcement support methods and loads will not adversely affect the performance of the waterproofing system.

The Contractor shall closely liaise with his concrete supplier, to ensure that a consistent concrete supply is maintained during concreting to reduce risks of cold joints being formed, thus weakening the element and increasing risk of future leakage.

The Contractor shall submit to the Architect, a specific detailed method statement for water-resisting construction. This shall address the major issues such as proposed concrete mix, construction joint locations, sequence and timing of pours, waterstops, quality control and checking procedures, key personnel and key sub-contractors details.

The Contractor shall take care to protect the freshly cast or cured concrete from early damage due to, early depropping, early loading or construction vibration (generators, walkways or driveways), which may cause early and excessive cracking.

The Contractor should consider the practice of re-vibration of the concrete elements at the appropriate time to eliminate plastic settlement cracks; this would be particularly beneficial in the suspended slab areas. The Contractor should note however that it shall be their decision/responsibility if they use this method.

3.15.2 General Recommendations

Methods of fixing formwork resulting in holes through the concrete section when the formwork is removed shall not be used.

Wall ties shall have water baffles. Pipes and sleeves shall have integral puddle flanges.

Except otherwise specified in the Drawings, all walls shall have kickers of minimum 150mm high cast monolithically with the base slab or pile caps. Supports for kicker formwork shall not penetrate through any water-resisting elements.

All pipes, sleeves, inserts, fixing etc shall be cast-in with the concrete. Coring and post-drilled fixing will not be permitted (See Clause 3.3.2).

Other applicable clauses in the Specification include but not limited to Clauses 2.8.1 and 2.8.2.

3.15.3 Position of Construction Joints

It is the Contractor's responsibility to decide where they locate the construction joints to achieve the necessary water-resisting construction. However, the following may be used for guidance. The maximum dimension of pours should not exceed:

- In slabs, more than 10m in any direction;
- In walls, maximum length 5m and maximum area 25m² unless as specified in the Drawings.

If the Contractor wishes to use significantly larger lengths, they should address curing and temperature control of the sections in their method statements together with design justification of the shrinkage effect.

The use of Hyrib type construction joints will not be permitted in areas of water-resisting construction as it is considered deleterious to the joint integrity.

3.15.4 Waterstops

Whether or not shown on the Drawings and notwithstanding the provision of external membranes, waterstops shall be provided in all construction joints and movement joints. The waterstops shall be of an approved type and fixed in accordance with the manufacturer's written instructions. Adequate provision shall be made to support and completely protect the waterstops during the progress of the work. Any waterstop punctured or damaged shall be repaired or replaced. Exposed waterstops shall be protected during

application of form release agents to avoid being coated. Suitable guards shall be provided to protect exposed projecting edges and ends of partially embedded waterstops from damage when concrete placement has been discontinued. All site splices shall be done by a competent person using proper equipment and procedures.

Where waterstops within the concrete section are proposed, the Contractor shall submit to the Architect for agreement details of the methods to be used to a) maintain the waterstops in their correct positions and to prevent damage while the concrete is being placed and during and after removal of the formwork; and b) ensure that the concrete around the waterstops is thoroughly compacted so that there is dense concrete adjacent to the waterstops. See also Clause 2.10.2.

Hydrophilic strips shall be fully enclosed in the concrete section and shall not be positioned in the concrete cover zone and shall be a minimum of 50mm clear distance from the nearest reinforcement face. Hydrophilic strip shall be continuously glued by an approved epoxy cement into a formed recess in the previous pour. Recesses shall be of similar width and half the depth of the strip. Ends to be joined shall be miter cut with sharp knife or shears. The ends shall be adhered with cyanoacrylate (super glue) adhesive. Once installed, adequate measures should be taken to prevent exposure to rain water, ground water, etc. before the joint is covered with concrete.

Hydrophilic waterstop strips shall not be used in movement joints or in any internal or above- ground construction joints, which are not permanently damp, for water-resisting application unless otherwise approved by the Architect.

3.16 Mortar

3.16.1 Cement Mortar

Cement mortar for structural work shall be mixed in the proportions of 1 part cement to 3 parts sand by volume. The sand shall be of natural sand or crushed natural stone or a combination of both complying with BS EN 13139.

Mortar shall be mixed thoroughly either by hand or mechanically until its colour and consistency are uniform. The constituent materials shall be accurately gauged, allowance being made for bulking of sand. Mortar shall be made in small quantities only as and when required. Mortar starting to set or having been mixed for more than one hour shall be discarded.

3.16.2 Dry Pack

Dry pack shall be a (1:1) stiff cement mortar composed of PC and fine aggregate which shall be thoroughly mixed with water to obtain a strength when rammed in standard cube moulds of not less than 30 N/mm² at 28 days. The mix shall have minimum water content compatible with achieving a consistency suitable for ramming into place using caulking tools.

3.16.3 Epoxy

Epoxy mortar shall comprise not more than 6.5 parts by weight of a suitable fine aggregate such as silica sand to one part by weight of approved epoxy mortar. The concrete surface shall be skilfully hammered to remove all laitance immediately before applying epoxy resin tack coat. The epoxy mortar shall then be laid and cured, all in accordance with the manufacturer's written instructions.

3.16.4 Cement Mortar and Grout for Drill-in Bars and Bearings

Cement mortar for bedding and construction of un-reinforced plinths for bearings shall be a proprietary non-shrink type approved by the Architect having a grade strength of at least 50MPa except otherwise stated in the Drawing.

Grout for grouting drill-in bars, base plates and holding down bolts shall be a proprietary non-shrink cementitious type approved by the Architect having a grade strength of at least 50MPa. The grout shall be flowable and shall not bleed or segregate. The suitability of the

grout shall be demonstrated by site trials to the approval of the Architect. Chemical-resin based grout shall not be used.

3.16.5 Cubes for Strength Tests

Where mortar is employed for structural work, cubes shall be made and tested to verify the strength of the mortar. Sampling shall be proposed by the Contractor.

3.17 Filling Openings for Services Penetrations

Where openings have been left through floors and walls to allow building services to penetrate through one compartment to another, the openings shall be filled after installation of the services.

Large openings such as pipe ducts shall be filled with the same grade of concrete as the adjacent structure. Small openings less than 100mm diameter such as sleeves for individual pipes shall be filled with 1:3 cement-sand dry packed mortar well rammed in. Before filling, the pipes or trunking shall be painted with bituminous paint or wrapped with anticorrosive tape. Where it is necessary to allow for expansion of the pipes, they shall be wrapped with compressible and fireproofing linings after painting.

3.18 Quality Assurance

3.18.1 Material Testing - Concrete and Reinforcement

Sampling of concrete and reinforcement, and testing of concrete cubes and reinforcement samples shall comply with the requirements of the HKB(C)R, PNAPs, CS1, & CS2 and the relevant approval letters for the Works from the BD.

For each consignment of cement or reinforcement, the Contractor shall obtain and keep on site a copy of the Manufacturer's certificate of tests (including for reinforcement bars, the rebend test) carried out in accordance with this specification.

Testing of concrete cubes and reinforcement shall be carried out by a laboratory approved for such tests through HOKLAS. The Contractor shall submit to the Architect for approval such details as the HOKLAS certificate, types of test approved through HOKLAS and job references etc of the laboratory selected.

The Contractor shall be responsible for observing requirements of the BD for testing of any material, and requirements for materials to be approved by BD before being used for the Works. The Contractor shall be familiar with such requirements that may be stated in the Building Regulations, PNAPs and BD approval letters for structural submissions and material submissions.

Apart from the above, the Contractor shall carry out any tests as necessary or as required by the Architect to ensure acceptable level of quality and performance of the Works.

3.18.2 Workmanship

The Contractor shall only employ persons or companies properly qualified to carry out special work or tests. Where applicable, the Contractor shall submit to the Architect certificates of proficiency of the persons and certificate of accreditation of the companies to be delegated or employed for doing the work or tests.

If the Architect is in doubt of the workmanship and quality of work done by any person employed by the Contractor, the Architect may request the Contractor to send that person to take relevant proficiency tests at the Contractor's cost.

3.18.3 Management

The Contractor shall operate an agreed quality management system to BS EN ISO 9000 and BS EN ISO 9001 unless otherwise agreed with the Architect, which shall be accessible for audit. All documentation shall be available for inspection during the contract period.

The Contractor shall submit to the Architect the names, curriculum vitae and job reference of the following personnel delegated to complete the Contract or carry out the Works:

- Director responsible for the Contract
- Contracts Manager responsible for the Contract
- Project Manager responsible for the Contract
- Programme planner
- Quantity surveyor
- ICE for formwork and falsework design and other temporary works including checking effects on permanent structures
- ICE for the Contractor design and build items
- Technical competent person for temporary works checking on site
- Site Agent
- Concreting foreman in charge
- Steel fixing foreman in charge
- Formwork foreman in charge
- Setting out foreman in charge
- Excavation foreman in charge
- Structural engineer
- Quality engineer whose duties include preparation of documents to be submitted to the BD

3.18.4 Quality Control

The minimum quality control measures for design and construction of the concrete works by the Contractor should comply with Section 11 of HKCC.

3.19 Defective Concrete

The Contractor's methods of making good any defects shall be submitted to the Architect for approval prior to start of remedial work. See also Clause 4.10.

4 PERFORMANCE AND TESTS

4.1 General

All tests, inspections and checks shall be carried out in the presence of or as directed by the Architect. The Contractor shall be responsible for carrying out all tests and inspections required by this Specification or called for by the Architect and shall arrange for copies of test results and inspection reports to be supplied to the Architect immediately when they are available.

A competent person shall be employed to supervise all stages, including preparation work, of testing of concrete and reinforcement. They shall also supervise all tests on materials and maintenance and calibration of all mixing and measuring equipment. For monitoring, controlling and taking samples of concrete, the Contractor shall employ a technician holding a Certificate in Concrete Technology (Level 2) from the Materials Division of the HKIE or a Certificate from the CITA Certification Course for Construction Materials Samplers.

4.2 Testing

4.2.1 General

Before commencement of the Works, the Contractor shall engage suitably qualified staff, to the Architect's approval, for carrying out tests required by this Specification. He shall submit

for the approval of the Architect the name and project reference of the HOKLAS certified testing laboratory he proposes to employ to carry out the tests. Unless noted otherwise they shall maintain on site the following pieces of apparatus which shall be kept in good condition throughout the Contract and shall remain the property of the Contractor:

- (a) Apparatus for assessing workability in accordance with CS1:1990, Construction Standard Testing Concrete Vol. 1 and 2.
- (b) Apparatus for making, curing, and weighing the concrete test cubes required by this Specification, all in accordance with CS1:1990.
- (c) A calibrated thermometer(s) to be kept on site close to the Works for measuring and record daily maximum and minimum atmospheric shade temperatures.
- (d) A soil thermometer for measuring concrete and ground temperature.
- (e) Temperature-controlled curing tanks for concrete cubes.
- (f) Rebound hammer (Schmidt) for testing concrete hardness. Calibrated by independent laboratory.

4.2.2 Water Tests

Water tests shall be carried out to all water tanks, pools and aqueous containing chambers etc., in accordance with BS 8007, or as directed by the Architect.

4.2.3 Test Nonconformity

- (a) Any test results which do not meet the specified criteria shall be reported to the Architect. In the light of this nonconformity, the Contractor shall propose a course of action to the Architect for agreement, within one week of reporting the results. The material to which the test nonconformity applies shall be deemed to be unacceptable unless further testing or analysis proves otherwise and all associated costs shall be borne by the Contractor. Any remedial work shall be at the Contractor's expense.
- (b) A course of action shall be agreed within a further week.

4.3 Testing of Cement and SCM

Cement and SCM shall be tested in accordance with relevant standards and the test frequencies shall comply with QSPSC Part 2 - Technical Regulations (Issue 6) published by HKQAA.

4.4 Testing of Aggregate

4.4.1 General

The Contractor shall be responsible for the application of the following clauses and tests to aggregate for structural concrete to be mixed on site, and for such application by the concrete supplier if ready-mixed concrete is used for the Works.

Where ready-mixed concrete is used, the Contractor shall obtain from the concrete supplier the test results to submit to the Architect for approval before commencement of the concrete works.

All sampling and testing of aggregate shall be carried out in accordance with BS 812.

4.4.2 Preliminary Tests

A HOKLAS approved laboratory shall carry out the following tests for the aggregate used:

- (a) Sieve analyses;
- (b) Tests for clay, silt and dust content;
- (c) Tests for organic impurities; and
- (d) Tests for salt content.

Tests (a) and (b), with tests for the moisture content of each aggregate, shall also be carried out on the samples used for each trial mix.

Test (c) shall comply with BS EN 12620 and BS EN 1744-1.

The Contractor shall submit to the Architect for approval certificates of recent tests giving the following information about the aggregate:

- Specific gravity
- Water absorption
- Ten percent fines value
- Flakiness and Elongation

4.4.3 Works Tests

The Contractor shall either take it upon himself or instruct the Concrete Supplier to carry out the above tests on the aggregate, from each size and from each source, as are necessary for the production of the specified concrete.

The minimum frequency of testing shall be as follows:

- (a) Sieve analysis – Once a day for each of the first ten days on delivery, and thereafter once a week or as required by the Architect.
- (b) Tests for clay, silt and dust – Once a day, until the Architect is satisfied with the results of the tests and their uniformity. Thereafter once a week or as required by the Architect.
- (c) Moisture content of coarse and fine aggregate – daily.
- (d) Specific gravity – twice per year.
- (e) Water absorption – twice per year.
- (f) Ten percent fines value – once per month.
- (g) Flakiness and Elongation – twice per year.
- (h) Potential Alkali Reactivity – see Clause 2.4.6.

Any aggregate delivered during the progress of the work which shows a variation in grading outside the range specified in BS EN 12620 shall be rejected.

The Contractor shall provide the Architect with a certificate for his record at such regular intervals as the Architect may prescribe from time to time showing that all aggregates have been tested since the date of the last such certificate and showing that all aggregates being used continue to comply with the requirements of this Specification.

4.5 Testing of Admixtures

The performance and uniformity tests of the admixtures in use shall be carried out in accordance with BS EN 480 and BS EN 934 for each product each month, provided always that the manufacturer's production quality control and quality system records according to BS EN ISO 9001 are available to support the claim of no change within the specified acceptance tolerances and such records are accepted by the Architect.

4.6 Testing of Concrete

4.6.1 General

The sampling of works concrete shall be in accordance with Regulation 58 and Table 7 of the HKB(C)R except that samples shall be taken at the mixer or at the point of placing or as directed, and that samples shall be taken on eight occasions on each of the first five days of using a mix. The batches from which samples are taken shall be chosen by the Architect or Engineer.

From each sample a minimum of two 150mm test cubes, made and cured in accordance with CS1, shall be taken for testing at 28 days.

All records of works concrete tests shall indicate clearly which part of the structure each sample of concrete represents.

Table 4.1: Sampling Rate Extracted from Table 7 of HKB(C)R

Type or Part of Building, Building Works or Street Works	Quantity of Concrete to be Represented by Each Sample
Cantilevers, columns, shear walls, prestressed and other critical elements	10 m ³ or 10 batches whichever is the smaller volume
Solid rafts, pile caps, caisson caps and mass concrete	100 m ³ or 100 batches whichever is the smaller volume
All other types or parts	25 m ³ or 25 batches whichever is the smaller volume

The workability of each sample shall be checked. Unless otherwise directed, the slump shall be within the following limits from the value determined for the trial mix:

For slump value below 100mm, $\pm 25\text{mm}$ or \pm one third of the design value, whichever is more stringent.

For slump value $\geq 100\text{mm}$, $\pm 50\text{mm}$ or \pm one third of the design value, whichever is more stringent.

If at any time the Architect is not satisfied that the ready-mixed concrete complies with this Specification they may alter the frequency of the sampling.

4.6.2 Sampling and Testing of Ready-mixed Concrete

Samples and tests shall be carried out to meet the requirements of the BD. Samples of concrete shall be taken in accordance with the requirements of this Specification at the point and time of delivery.

Each concrete mix shall be sampled and tested in accordance with Clause 5.4.1 of BS EN 206-1: 2000 for consistence at least once a day for the first five days on which the mix is delivered to site, and thereafter as directed.

In accordance with Clause 8.2.1 of BS EN 206-1: 2000 samples of each mix shall be taken at the mixer at least once each day when concrete of that mix is delivered. For each sample, **workability tests** shall be carried out and two cubes shall be made, one for test at 7 days and the other for test at 28 days. The results of these tests shall be submitted to the Architect within a week of the tests, with copies of the manufacturer's certificates for each type of cement used.

A slump test shall be carried out in accordance with CS1 or directed by the Architect on each batch of concrete delivered to site. The whole batch of concrete shall not be placed in the permanent works if the result of any test for workability, carried out on a sample taken from the batch, does not comply with the requirements for workability as specified in this Specification.

4.6.3 Statistical Analyses of Cube Test Results

The Contractor shall prepare statistical analyses and other calculations of cube results in accordance with HKB(C)R requirements and submit them to the Architect for information and record.

4.6.4 Schmidt Hammer Test

The Contractor shall carry out Schmidt Hammer Test as required by the BD and/or directed by the Architect to supplement the cube test and core test results to the grade strength of the in-situ concrete works.

4.6.5 Salts

Tests for salt content of hardened concrete specimens shall be made in accordance with CS1 as directed by the Architect.

4.6.6 Slump-flow Testing

Slump-flow testing shall be used to replace slump testing as a workability acceptance test for Self Compacting Concrete and High Flow Concrete. Slump-flow testing of concrete shall be carried out to ISO 1920-2: 2005. Where appropriate the slump equipment described in CS1 shall be used instead of that referenced in the ISO document.

4.6.7 Test Failure of Works Concrete

Notwithstanding the recommendations in Regulation 59 of the HKB(C)R, the Architect will assess the effect of any cube results falling below the designed strength of the concrete in relation to the location of the sampled batch, and may reject or call for further investigation by means of non-destructive tests and/or, if applicable, taking and testing of cores in accordance with CS1 to demonstrate the adequacy of that part of the structure. The coring test requirements shall comply with Clause 5.2.10. If such investigation reveals that the grade strength of the in-situ concrete is not attained, that part of work shall be condemned and replaced as directed by the Architect at the Contractor's expense. The Contractor may be required to stop concreting in other parts of the structure until the rectification work is completed to the satisfaction of the Architect.

4.6.8 Measuring Equipment for Concrete Mixing

The accuracy of the measuring equipment shall be within $\pm 2.5\%$ of the quantity of cement, water or total aggregate being measured and within $\pm 5\%$ of the quantity of any admixture being used. All measuring equipment shall be maintained in a clean, serviceable and accurate condition. The accuracy of each scale shall be checked daily at its zero. Re-calibration of the weighing equipment by the manufacturer or his agent shall be undertaken at intervals of not more than 3 months.

4.7 Testing of Reinforcement

4.7.1 General

Testing of reinforcement shall be carried out by a laboratory approved through HOKLAS for such tests. The Contractor shall submit to the Architect for approval the details, such as the HOKLAS certificate, types of test approved by HOKLAS and job references etc of the selected laboratory.

Should any test specimens fail to comply with this Specification, the Architect may require further tests all at the Contractor's expense, or reject the whole or part of the particular consignment, which must be immediately removed from the site.

Test reports in compliance with the BD requirements shall be furnished to the Architect and RSE.

4.7.2 Sampling and Testing of Steel Reinforcement Bars

Every batch of steel reinforcement bars delivered to the site shall be sampled and tested in accordance with PNAP 122 or CS2 and the relevant approval letters for the Works from the BD.

The Contractor shall ensure that the tests are in compliance with the current edition of PNAP 122 or CS2, which may be revised by the BD throughout the duration of the Contract.

4.7.3 Fabric Reinforcement

Every batch of welded fabric reinforcement delivered to the site shall be sampled and tested in accordance with BS 4483 and BS EN ISO 15630 Part 1 and Part 2.

4.7.4 Testing of Reinforcement Couplers

Where an approved type of reinforcement coupler is used and there is no BD requirement for tests of the type, the Contractor shall carry out tensile tests for three samples of each diameter of couplers to be used for the Works in three months interval or one sample per batch of less than 100 in number or at 1% of the quantity used for the whole Works whichever is the greater as directed by the Architect.

The test shall demonstrate the compliance to BS 4449 and the following requirements:

- (a) The preferred failure mode of the couplers is a bar-break failure, defined as a failure occurring away from the coupler, at a distance of at least 2 bar diameters.
- (b) If bar break is not achieved, then the connection shall reach at least 95% of the actual tensile strength of the bar, measured on a control bar from the same batch, and shall have a ductility of at least 5% measured as the elongation at maximum load (A_{gt}).
- (c) The permanent elongation after loading to 60% yield strength (f_y) shall not exceed 0.1mm.

The test results shall be submitted to the Architect for record.

4.8 Testing of Cast-in and Drill-in Items

The Contractor shall carry out loading test of the structural cast-in and drill-in items as may be required by the BD at his own cost and time.

The Architect subject to his discretion may instruct the Contractor to carry out loading test of the structural cast-in and drill-in items to prove the capacity. The test load shall be 1.5 times the recommended working load in the direction of application of the design load. The cost and time incurred shall be borne by the Employer if the test result is found satisfactory to the Architect, otherwise by the Contractor.

See also Annex A for Drill-in Anchors.

4.9 Setting out and Tolerances

4.9.1 General

The permitted deviations specified in this section are **NOT** cumulative. Permitted deviations are of individual components and where it is necessary to combine permitted deviations to establish the acceptability of the position of the structural work, the deviations shall be combined using the root sum square method as recommended in Clause 9.4 of BS 5606.

The Contractor shall carry out regular checks on the structure. If an accumulation of tolerances results in a position which is out of the permissible deviations as specified in this Specification, BS 5606 and Clause 10.2 of the HKCC, whichever is more stringent, the Contractor shall propose remedial measures for agreement with the Architect prior to carry out any rectification works. The Contractor shall liaise with all Sub-Contractors and advise the Architect on more stringent requirements in related to the acceptable structural tolerances prior to commencement of Works.

When required by the Architect, the contractor shall furnish all necessary instruments and labour all at his own cost for the use of the Architect for checking the finished concrete.

4.9.2 Datum References

At commencement of the Contract, the Contractor shall agree with the Architect the government bench marks as datum levels and for the purpose of setting out the gridlines for the Works.

The Contractor shall obtain the setting out dimensions from the Architect to set out the gridlines, and shall be responsible for the accuracy of his work. Figured dimensions shown on the Drawings shall be taken and the Contractor shall verify all such dimensions and levels before commencement of execution of the Works. The checking of any setting-out or of any line or level by the Architect or his representatives shall not in any way relieve the Contractor of his responsibility for the accuracy.

At every structural level, the Contractor shall establish both a datum level and a horizontal reference grid which shall be related back to the approved base bench mark and base reference grid in the forms agreed by the Architect.

4.9.3 Structural Members

Unless otherwise directed structural members shall be set out from the reference grids and datum levels, and constructed such that the dimension between any two points on different

constructed structural members, or between any two points on the same constructed structural member, or between any point on a constructed structural member and any reference grid or datum level, or the formed elements shall agree with the required dimension, whether shown on or calculable from the Drawings, within the degree of accuracy as stipulated in Clause 4.9.1.

4.9.4 Cast-In Fixings and Starters Bars

All cast-in fixings and starter bars shall be located within 10mm of the specified location. The Contractor shall liaise with the Nominated Sub-Contractors and advise the Architect if a more stringent tolerance is required.

4.9.5 Vertical Shafts

The maximum deviation in plumb for any vertical shaft used by hoists or lifts shall not be in excess of the permissible tolerances given in BS 5655-6 or in Clause 4.9.1 of this Specification whichever is the lesser.

The Contractor shall liaise with the Architect on the acceptable tolerances in advance of concreting.

4.9.6 Measuring Equipment

Tapes used for setting out the Works shall comply with BS 4035 and BS 4484-1. A reference tape shall be kept to check the accuracy of all working tapes. The Contractor shall ensure that all other setting out and measuring equipment is adequate to achieve the accuracies required by this Specification.

4.9.7 Dimensions of Completed Work

The Contractor shall keep records in an approved form of the dimensions of all work as constructed.

These records shall be available for inspection at any time and shall be submitted to the Architect as an as-built record plan immediately after completion of each section.

4.10 Defective Work

4.10.1 General

If any of the finished works, materials, tests or workmanship in any part of the Works fails to comply with this Specification, that part of the works will be classed as defective.

All works classed as defective shall be rectified without due delay. The Contractor shall submit a remedial work proposal to the Architect for approval prior to execution of the remedial work, unless the Architect provides direction to the Contractor for the remedial work or tests to demonstrate acceptability of the work. The Architect may order testing and if found defective, order the defective works to be cut out and properly reconstructed. Such cutting out shall extend to a position suitable, in the opinion of the Architect, for a construction joint.

If the works are proved defective, the Contractor shall bear all the costs and effects on programme incurred by investigation and remedial work for defective work.

4.10.2 Surface Cracking

The Contractor shall take all reasonable actions to minimise surface cracking. Cracking that will allow corrosion of reinforcement, unsightliness, unacceptable water leakage, impair durability or reduce structural adequacy shall be rectified by the Contractor as agreed with the Architect.

4.10.3 Water-resisting Construction

In construction specified on the Drawings as water-resisting, any leaks or damp patches shall be repaired in accordance with a method statement proposed by the Contractor and approved by the Architect.

4.10.4 Testing to Establish Acceptability of Work

Where the Works fail to comply with this Specification or the works concrete cubes fail to reach the required strength, the Architect will not necessarily accept the results of any tests proposed by the Contractor as proof of adequate material quality or workmanship.

4.10.5 Defective Appearance

Where the concreting of a part of the works is interrupted before the approved position of a construction joint is reached and the intended appearance of the concrete is thereby spoilt, that part of the works will be treated as defective work.

Any surface which is marred by rubbish left in the formwork, and (when using smooth-surfaced formwork) any surface which is discoloured by leakage of water or grout will be treated as defective works.

4.11 Load Tests

Where the works is constructed with dubious material or workmanship, the Architect may require load tests be carried out on the dubious works and the expenses so incurred shall be borne by the Contractor if the work is proved defective.

Test criteria and standards of acceptance shall be in accordance with Section 13 of the HKCC except otherwise specified by the Architect to satisfy the design intent. In normal case, the following test loads and sequence will be applicable:

- (a) The test load including self weight of the structure shall be the greater of: (i) the sum of the characteristic dead load and 1.25 times the characteristic imposed load; or (ii) 1.125 times the sum of the characteristic dead and imposed load.
- (b) Test loads shall be applied and removed in 25% increments, and allowing at least five minutes after a load increment is applied before recording deformation measurements.
- (c) The maximum test load shall be maintained for a period of 24 hours before removal.

Assessment of results shall be made by the Architect with due regard to the material strength, stress or other characteristics in the as-built structures, and with regard to the comparison of the measured performance with that expected on the basis of design calculation. In normal case, the structure under test shall be deemed to be satisfactory if all the following criteria are met:

- (a) no structure defects, signs of weakness or faulty construction are observed;
- (b) the maximum deflection of a member during the test does not exceed $1/360$ of its span or, for cantilevered members, $1/180$ of its span; and
- (c) within 24 hours after removal of the test load, the recovery of deformation is at least 75% of the maximum deformation during test.

If the recovery of deformation is less than 75% but is not less than 50%, a retest may be carried out adopting the same test load and sequences. The structure shall be deemed to be satisfactory if in this retest all the above three criteria are met.

The contractor shall submit the method statement and carry out all proper precautions during the load test.

Where results of such tests indicate that any part of the works does not comply with this Specification that part of the works will be classified as defective work.

5 HIGH STRENGTH CONCRETES (GRADE 60-100 MPA)

5.1 General

5.1.1 Application

The provisions of Sections 1 to 4 of this Specification shall apply; the following additional requirements shall apply to Grade 60-100 MPa concretes only. In the event of any conflict, the requirements of this section shall supersede and take precedence over the other sections.

5.1.2 Special Requirements

The Contractor's attention is drawn to the following special requirements for Grade 60-100 concretes [items (h) to (j) apply to Grade 100 concrete only]:

(a) Quality Assurance

All High Strength Concretes shall be subject to a comprehensive quality assurance programme extending from the supply of materials for the concrete to the final curing procedures on site. Details of the proposed scheme shall be submitted at least 8 weeks prior to elements being required. The scheme will be operated by the Contractor with checks by the Architect. The scheme shall cover the items listed in Clause 5.5.

(b) Temperature Control

The peak in-situ temperature specified in Clause 3.9.3 may be relaxed to 85°C, provided that:

- the concrete shall contain a minimum of 25% PFA or 50% GGBS by weight of cementitious material; and
- the PC shall have an SO_3^- content of less than 2.5%; and
- the total alkali content of the concrete is less than 3kg/m^3 when determined as in PNAP 180; and
- the water / cement ratio of the concrete is less than 0.40; and
- temperature and strength monitoring of the concrete is conducted.

The Contractor is advised that the peak temperature of high strength concrete is likely to exceed 85°C in Hong Kong unless appropriate measures are taken to reduce it, such as adjusting the mix design, insulating formwork, reducing the delivery temperature (by using liquid nitrogen cooling if necessary), or even internal cooling measures such as those achieved by introducing cooling pipes. The Contractor should explore measures of controlling temperatures and temperature gradient and shall submit a temperature control proposal not less than 8 weeks prior to first scheduled pouring of High Strength Concrete.

(c) Demonstration Elements

For concretes higher than Grade 60, for each construction method proposed by the Contractor for each mix, the Contractor is required to build one demonstration element on site to demonstrate his methods of construction and temperature control to the satisfaction of the Architect, prior to the commencement of elements construction in the building. These demonstration elements shall represent the elements in which concrete higher than Grade 60 is used and shall be subject to monitoring and testing as described in Clause 5.3.

(d) Compliance Testing

The Contractor is advised that an increase in the number of tests is required and that special provisions are necessary for compliance with testing of concrete to ensure validity of results and as described in Clauses 5.2 and 5.4.

(e) Coring

The Contractor is required to extract and test 100mm diameter cores for compressive strength from the structure which are to be used as final compliance check for the concrete as described in Clauses 5.2.10 and 5.4.8(q).

(f) Submissions

The following submissions are required at least two weeks before casting of any demonstration column:

- i) Mix design
- ii) Temperature control proposals
- iii) Curing
- iv) Quality assurance procedures
- v) Strength compliance

(g) Control of Alkali Silica Reactivity

The Contractor shall carry out tests on all aggregate for potential alkali reactivity by an independent laboratory approved by the Architect using the 'Accelerated Mortar Bar Test' to RILEM AAR-2. The aggregate shall be considered acceptable if the average expansion result at 16 days is less than 0.15%. Each type of aggregate shall be tested initially, prior to supply, and then at a minimum frequency of twice per year. If any aggregate is likely to exceed the limit, Contractor shall seek prior approval from the Architect and carry out an accelerated mortar bar test on the actual mix design to RILEM AAR-2 (grading the aggregates to achieve the specified grading) with expansion less than 0.15% at 16 days.

(h) Control of Thermal Cracking

The Contractor shall propose suitable methods of protecting the cast concrete in order to ensure that the risk of cracking, from water loss, peak temperature and temperature differential, is minimised and that peak temperature and temperature differential are retained within the maximum allowable temperature. The Contractor shall demonstrate by means of calculations and trials that the proposed concrete mix and method of concreting is adequate to control cracking. The Contractor shall make allowance to conduct stress analysis by a computer program approved by the Architect and in-situ stress measurement of trial element in order to assess the risk of cracking.

(i) Concrete Creep and Shrinkage

The long-term deformation effect of concrete by creep and shrinkage shall be evaluated by laboratory tests in an approved body. The shortening effect shall be comparable to normal graded concrete. The following tests are required:

- Concrete creep test to ASTM C512-02 using 100x200mm concrete cylinders instead of 150x300mm. 3 specimens shall be prepared for each mix.
- Shrinkage measured in parallel with the creep specimens (i.e. same curing and environmental exposure conditions throughout the testing) on unloaded specimens. 2 specimens shall be prepared for each mix.
- 2 nos. of standard 150mm cube strength tests and 150mm cylinder elastic modulus test to CS1 at 28 days shall be conducted.
- The creep specimens shall be loaded at an age of 7 days with a loading of 0.3 times the cube strength at 7 days and the loading is adjusted to 0.3 times the work strength of the specified concrete grade at 28 days.
- Creep and Shrinkage to be taken at the following times:
 - Immediately before first creep measurement
 - 3 hours after first creep measurement
 - Daily for first week

- Weekly for next 12 weeks
- Monthly for next 3 months

(j) Pumping Trial

Pumping tests shall be conducted by the contractor to satisfy the requirements for placing the concrete and achieving the workability without significant loss of properties. Slump/Slump flow test shall be conducted at the point of placement of the concrete after pumping as necessary to demonstrate that this is being achieved to the satisfaction of the Architect.

(k) Fire Performance

The Contractor shall ensure the proposed design mix complies with Clause 4.3 of HKCC and all applicable requirements in the Code of Practice for Fire Resisting Construction 1996. Relevant factors that could minimize spalling of concrete should be considered in the high strength concrete including type of aggregate used, control of silica fume content, moisture content, permeability of concrete and possible heating rate etc. The Contractor shall demonstrate (by local experience, specialist literature review or by testing) that practical means of control is taken in place to reduce risk of spalling that may occur under fire exposure.

5.2 Materials

5.2.1 Types of Cement

The cement shall be PC and supplied from one stated source.

PPFAC and Portland blastfurnace slag cement complying with BS 146: 2002 (BS EN 197-4: 2004 may be used to replace BS 146: 2002) may only be used where approved by the Architect. The level of PFA or GGBS in the cement used throughout the works shall remain constant and be approved by the Architect.

All the cements shall achieve a strength guaranteed to within ± 5 N/mm² when concrete cubes are tested at 28 days to BS 4550: Part 3: Section 3.4: 1978 (amended 1988).

No mixtures of cements of different type will be permitted.

5.2.2 Silica Fume (Microsilica)

Silica fume mineral admixture, also known as microsilica, shall conform to Canadian Standard CAN/CSA-A23.5-98 or ASTM C1240-05. All silica fumes shall come from the same single, proprietary source. Microsilica may be used with any cement specified in Clause 5.2.1.

5.2.3 PFA

PFA shall only be used with PC. Mixtures of PFA with any blended cement will not be permitted. All PFA shall come from the same single, proprietary source. PFA content, which complies with Clause 4.2.5.5 of the HKCC, shall be a minimum of 25% by mass of the total cementitious content of the concrete.

5.2.4 Ground Granulated Blastfurnace Slag (GGBS)

GGBS shall only be used with PC. Mixtures of GGBS with any blended cement will not be permitted. All GGBS shall come from the same single, proprietary source. The maximum GGBS content, by mass of the total cementitious content of the concrete, shall not exceed 50%. For large sections that require to control the heat of hydration or for sulphate resisting concrete, the GGBS content may be increased to 70% subject to the approval of the Architect.

5.2.5 Aggregates

Aggregates shall achieve a minimum TFV of 150kN for concrete grade inferior to 70MPa and 170kN for concrete grade 70MPa and above using BS 812-111, and shall comply with all other requirements of BS 812.

In addition to the requirements for flakiness and elongation in this Standard Specification, the combined indices for flakiness and elongation for coarse aggregates used for high strength concrete shall not exceed 50%.

5.2.6 Designed Concrete Mixes

High Strength Concretes shall comply with the mix requirements stated in Table 5.1 (NR means no requirements).

No additional water is permitted to adjust slump. All slump adjustment is to be made using admixtures.

Table 5.1

Requirements	Max	Min
Total Cementitious content (kg/m^3) (See Notes)	600	300
Water/total cementitious content ratio	0.4	NR
Nominal coarse aggregate size (mm)	20	10
Slump at site (mm)	NR	100
Temperature of wet concrete at time of placing °C	25	NR
Notes: 1. For Grade 60 concrete, the total cementitious content shall not in excess of 550kg/m ³ . 2. The cement content should be limited to not more than 450kg/m ³ .		

5.2.7 Trial Mixes

Five trial plant mixes shall be carried out using the same equipment and at the same plant intended for supply of the concrete. Each trial mix shall be carried out on a separate day and shall consist of a 3m³ (minimum size) batch from which the following tests and sample shall be taken from the beginning, middle and end of each batch; after due allowance is made for the time between mixing and placing.

- Temperature
- Slump
- 6 no. cubes

The cubes shall be tested for the 7, 14 and 28 day compressive strength to the requirements of this Specification at an independent HOKLAS approved laboratory and the 28 days results obtained from the 100mm cubes shall comply with the following criteria for acceptance of the trial mix:

- (a) The mean strength of the 28 days results shall exceed the characteristic strength plus 12 MPa.
- (b) No single strength result shall fall below the characteristic strength plus 5 MPa.

In addition to tests on trial mixes to verify compliance with strength requirements, trial mixes shall also be utilised to investigate workability, setting times, and slump loss changes for the mix proposed using various dosages of admixture and different ambient and concrete temperatures.

5.2.8 Concrete Production

Concrete suppliers shall operate a quality assurance scheme meeting the requirements of the QSPSC of the HKQAA or BS 8500 and BS EN 206-1; and shall cover all aspects of material supply, quality, batching, mixing, transportation, and properties of the concrete. Provision shall be made for the actual quantities of materials contained in each batch of

concrete to be recorded automatically and the method by which this is to be documented shall be subject to endorsement by the Architect.

The adjustment of slump by dosing admixtures into the concrete should take place not more than two times and each adjustment must be followed with remixing for at least 5 minutes.

If necessary facilities should be set up on site for dispensing admixtures into ready mix concrete for the purposes of controlling slump and setting time. This facility shall be provided and operated by the ready mix concrete supplier.

The ready mix supplier shall provide qualified concrete technicians on site to determine and control the amount of admixture required to be added on site. The technician shall hold a certificate in Concrete Technology (Level 2) from the Materials Division of the Hong Kong Institute of Engineers, or an approved equivalent certification.

5.2.9 Cube Testing Compliance Criteria

The cube testing compliance criteria shall be in accordance with the HKB(C)R requirements using 150mm cube specimens. Specimens of 100mm cube complying with the acceptable criteria stated in Table 5.2 may be used subject to the acceptance by BD.

If 100mm control cubes is to be used the Contractor shall make proposal to the Architect in writing, at least 3 months before the commencement of concrete Works, in order to obtain BD's approval for the exemption of Regulation 58 of the HKB(C)R.

Table 5.2

Compliance Criteria for 100mm Cube	Column A	Column B
	Average of any four consecutive test results shall exceed the specified grade strength by at least	Any individual test result shall not be less than the specified grade strength minus
C1	7 MPa	2 MPa
C2	5 MPa	2 MPa
Note: Compliance criteria C2 shall apply if in the opinion of the Architect there is sufficient evidence that the standard of quality control using similar materials and plant is such that the standard deviation for at least 40 test results will not exceed 5.5 MPa.		

5.2.10 Core Testing Requirements

Concrete cores shall not show evidence of segregation or honeycombing which in the opinion of the Architect is excessive.

Concrete cores shall be capped with sulphur compound with a compressive strength of not less than the core. The thickness of the cap shall not exceed 5mm and made of the same material for all cores.

The test results 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 unless permitted by the Architect. The estimated equivalent cube strength of each core specimen shall be calculated in accordance with CS1. 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.

5.2.11 Formwork

The formwork to be adopted for the high strength concrete shall be of the type and design appropriate for the concrete properties including higher fluidity, longer setting time and higher heat content than conventional concrete. Formwork shall be impermeable to prevent moisture loss from the newly poured concrete before stripping of formwork and commencement of curing.

5.3 Workmanship and Construction

5.3.1 Demonstration

(a) General

Where required, one demonstration element to represent the element sizes being used on site shall be poured at least 40 days prior to commencement of concrete placing to demonstrate the Contractor's method of construction and temperature control. The demonstration elements shall contain the full reinforcement condition of the typical columns to be used in the permanent works. These columns will be used to check and agree with the following:

- site QA procedures, slump adjustment and monitoring procedures, setting times and HKB(C)R strength requirements;
- adequacy of steel fixing and reinforcement spacing;
- adequacy of formwork for grout tightness, rigidity, alignment, and surface finish;
- curing proposals including measures complying with Clause 3.9.2;
- strength of concrete by coring (12 nos. per trial column);
- coring methods;
- rate of gain of strength using matched curing;
- non-destructive testing as directed by the Architect.

Should any demonstration element fail to demonstrate the adequacy of the Contractor's proposals to meet the requirements of this Specification, then the Contractor shall undertake such extra demonstrations as are necessary to demonstrate the adequacy of his proposals.

(b) Heat of Hydration

The Contractor shall make proposals for achieving the requirements of Clauses 3.9.1, 3.9.2, 3.9.3 and 5.1.2(b) in respect of the effect on heat of hydration. The demonstration elements as stated above shall demonstrate the adequacy of these proposals to meet the requirements of the specification in respect of temperature control. They shall be fully instrumented to record temperatures at 20 locations at 15 minutes intervals for at least 72 hours, as directed by the Architect. Provision shall be made for testing of the concrete as indicated above.

5.3.2 Placing and Compaction

(a) Placing

High Strength Concrete shall not be placed in any part of the Works until approval has been given. All placing and compacting should be carried out under suitable supervision and as soon after mixing as is practicable. Transporting, placing and compaction of a batch shall be completed within 45 minutes after arrival on site. Delays in placing may be permitted provided that the concrete can still be placed and fully compacted without the addition of further water or admixtures. Protection to exposed concrete surfaces from direct sunlight shall be in place 30 minutes after compaction.

Concrete shall be placed continuously up to construction joints while it is still sufficiently plastic for adequate compaction.

(b) Compaction

Internal vibrators shall operate at not less than 10,000 cycles per minute. For compacting the test cubes and cylinders a vibrating table operating at not less than 3,000 cycles per minute shall be used.

5.3.3 Curing

Immediately upon removing the column formwork, the sections shall be wrapped in 2000 gauge polythene with the polythene edges overlapped by at least 400mm and fully sealed all the way around the edge by 100mm wide PVC tape. Curing shall be maintained for a period of at least 10 days. Other measures of curing protection may be allowed with the approval of the Architect.

5.3.4 Making Good

No structural making good of high strength concrete will be permitted except to repair core holes where the strength and durability of the concrete should remain unimpaired.

5.4 Performance and Tests

5.4.1 General

The tests shall be conducted for materials from each size (where applicable) and from each source; and "each batch" cited in these clauses shall be any quantity of the material of the same type, manufactured or produced at the same time in the same place, covered by the same certificates and delivered to the Site, or stored at the ready-mixed concrete plant, at any one time.

5.4.2 Cement

One set of full physical tests shall be carried out in accordance with BS 4550 and BS EN 196 on each batch of cement used; and thereafter twice per week on the same batch.

One set of full chemical analysis tests shall be carried out in accordance with BS EN 196 on each batch of cement used; and thereafter once a year for concrete grade inferior to 70MPa and once a month for concrete grade 70MPa and above on the same batch.

5.4.3 Silica Fume (Microsilica)

The Contractor shall certify that all silica fume used complies fully with Canadian Standard CAN/CSA-A23.5-98 or ASTM C1240-05.

Each batch of silica fume delivered shall be tested by an approved independent testing laboratory for compliance with Canadian Standard CAN/CSA-A23.5-98 or ASTM C1240-05 and for the following chemical and physical requirements:

(a) Chemical Requirements

Silicon dioxide (SiO ₂), minimum, percent	85.0
Sulphur trioxide (SO ₃), maximum, percent	3.0
Loss on ignition, maximum, percent	7.0

(b) Physical Requirements

Fineness: Amount retained when wet sieved, on 45µm sieve, percent	0
Pozzolanic Activity Index: With PC, determined at 7 days and 28 days, minimum percent of control	100

5.4.4 Pulverised Fuel Ash

Acceptance upon delivery: Each delivery of PFA shall be accompanied by a certificate of compliance with BS 3892-1: 1997 stating the chemical compositions, the moisture content, loss on ignition and fineness (45µm sieve).

Sampling and testing: a) Physical Test – From each batch used, sample shall be taken once per week or every 1000m³ concrete production by the concrete supplier; and b) Chemical Test – From each batch used, sample shall be taken once per year by the concrete supplier. The samples will be delivered to the concrete supplier's quality control laboratory and tested in accordance with BS 3892-1:1997.

Regular tests carried out by an independent laboratory: Every month a sample shall be taken from the batching plant to be delivered to an independent HOKLAS approved

laboratory to carry out all the chemical analysis and the physical tests required in the BS 3892-1: 1997.

5.4.5 Ground Granulated Blastfurnace Slag (GGBS)

Acceptance upon delivery: Each delivery of GGBS shall be accompanied by a certificate of compliance with BS 6699 stating the chemical compositions, the moisture content, loss on ignition and fineness (80µm sieve).

Sampling and testing: a) Physical Test – From each batch used, sample shall be taken once per week or every 1000m³ concrete production by the concrete supplier; and b) Chemical Test – From each batch used, sample shall be taken twice per year by the concrete supplier. The samples will be delivered to the concrete supplier's quality control laboratory and tested in accordance with BS 6699.

Regular tests carried out by an independent laboratory: Every month a sample shall be taken from the batching plant to be delivered to an independent HOKLAS approved laboratory to carry out all the chemical analysis and the physical tests required in the BS 6699.

5.4.6 Aggregates

The tests described in Clause 4.4.3 shall be carried out except the test frequencies specified otherwise as follows:

- Sieve analysis shall be carried out once per day for concrete grade 70MPa and above.
- Tests for clay, silt and dust shall be carried out once per day.

In addition, tests for TFV, elongation and flakiness indices shall be carried out on each new batch delivered; and the test for potential alkali reactivity shall comply with Clause 2.4.6.

5.4.7 Admixtures

In addition to Clause 4.5, each batch of admixture shall be tested to BS EN 480 and BS EN 934 and shall be accompanied by a certificate of testing which includes the test results.

5.4.8 Testing of Concrete

Consistency Test

- (a) Slump or slump flow tests shall be performed for each batch of concrete delivered to site. Slump tests shall achieve $\pm 50\text{mm}$ or \pm one third of the agreed design value, whichever is more stringent, subject to the minimum figure in Clause 5.2.6. Slump flow values and testing criteria shall refer to Clauses 2.8.2 and 4.6.6 respectively.
- (b) Slump/consistency tests shall be carried out both prior to and after the addition of admixture on site to achieve the required workability. Where necessary, workability measurements should be made at the placement location of the concrete.
- (c) A secure, air conditioned lockable facility shall be set up on site by the Contractor under the control of the quality control engineer to provide site testing requirements.

Concrete Cube Test

- (d) Concrete cubes as required shall be taken for each batch of concrete delivered to site. Only approved concrete test moulds complying with the relevant standards shall be used.
- (e) Concrete cubes should in general be taken after the final adjustment of workability by admixtures has been made, but two additional 150mm cubes and two additional 100mm cubes should be taken before adjustment in one out of every five batches of concrete.
- (f) All cubes made on site shall be compacted using a vibrating table.
- (g) The surface of samples shall be steel-trowelled smooth after the application of an approved polymer latex solution. The latex solution shall be diluted in the proportion of 1 part of latex to 2 parts of water.

- (h) Samples shall only be marked by wax crayon or ink. The concrete shall not be "scribed" or marked in any manner on surfaces intended to be placed in a test machine.
- (i) Concrete cubes shall be cured at an off site HOKLAS certified laboratory.
- (j) For each truckload of concrete, 150mm concrete cubes shall be tested for compressive strength, two at 28 days and two at 7 days if proof of early age strength is required. The testing laboratory should be made aware of the possible high strength at 28 days and they should make arrangement to use a fully accredited and calibrated compression testing machine having the necessary loading capacity.
- (k) All cubes shall be water cured in a temperature controlled tank (at $27\pm 3^{\circ}\text{C}$) containing clean, circulating water for a period of not less than three days after demoulding.
- (l) All testing shall be carried by laboratories holding current HOKLAS approval for conducting the relevant tests.
- (m) For 100MPa concrete, a test machine shall be dedicated to the project and shall be calibrated each month by the approved test laboratory. Any effects of compression impact failure loads shall be immediately reported, and if necessary, the machine shall be mounted on an energy absorption base.

The test machine must have smooth, clean and dry platens to ensure a constant coefficient of friction between the platens and the sample.

The test machine should not be operated at more than 75% of the calibrated machine capacity.

- (n) The cubes should be centrally placed in the test machine. Cubes showing evidence of platen markings shall be rejected.
- (o) The rate of loading applied by the machine to the cube shall be in accordance with CS1.

The machine shall be adjustable to apply a rapid rate of loading to crush the cube to failure and to exhibit the concrete failure mode once the maximum test cube load is exceeded.

- (p) After failure, each concrete test cube shall be examined for proof of concentric loading and concentric concrete reaction by measuring the eccentricity of the load circle relative to the geometric centre of each of the compression faces. Cubes having an eccentricity of more than 25mm and/or an abnormal mode of failure shall be rejected.

Concrete Core Test

- (q) The Contractor shall make allowance for taking two 100mm diameter concrete cores from each of the elements on each floor at an age of 28-35 days. The core ends should be capped with high strength sulphur capping compound. The cores shall be tested for the compressive strength at an age not greater than 40 days. The Contractor shall make good the voids remaining after coring with a material having a strength not less than the surrounding concrete. Locations of cores shall be agreed in advance and steel reinforcement shall be placed to compensate for the loss of section.

5.5 Quality Assurance

A fully qualified quality control engineer shall be present on site during the construction of concrete work and be responsible for the quality of the concrete as defined above and the implementation of the quality assurance scheme.

Annex A: Construction, Performance and Test of Drill-in Anchors

A1 Construction and Performance

The drill-in anchors shall comply with Clauses 2.10.3 and 4.8 of this Specification and the following requirements:

- (a) Qualified site supervision of the drilled-in anchor works by an experienced and competent person should be provided to ensure that the works are carried out in accordance with the plans approved by BD and that the required standards are complied with.
- (b) Strength tests on a representative number of the drilled-in anchors, as directed by the Architect, are required to be carried out in accordance with the test criteria specified in paragraph A2 below and should be carried out by a recognized laboratory independent of the Contractor.
- (c) A method statement on the anchor tests mentioned under item (b) above is required to be submitted to the Architect for BD submission prior to the application for consent to the commencement of the drill-in works.
- (d) Upon completion of the works, a report is required to be submitted to the Architect, which should include:
 - (i) All results of the strength tests of the drilled-in anchors.
 - (ii) A discussion on any problems encountered during the installation of the anchor bolts and how they were overcome.
 - (iii) A statement signed by the Contractor's structural engineer to confirm that all drilled-in anchors have been installed in accordance with the manufacturer's recommendations.

A2 Testing

Strength tests of the drilled-in anchors should satisfy the following criteria:

- (a) Sampling rate should be i) at least 5% of anchors acting in shear and 10% of anchors acting in tension or 5 numbers each, whichever is more, of each type and size of the anchors installed; or ii) as required by BD whichever is more stringent.
- (b) Each representative anchor should be tested for tensile load by pullout test or shear load by shear load test as appropriate.
- (c) Test load should not be less than 1.5 times the recommended working load of the anchor as specified by the anchor manufacturer.
- (d) Upon the maximum test load is reached, the load should be maintained for at least one hour, and the readings of load and deformation should be taken at the beginning and end of this period to establish whether the tested anchor is subject to creep and relaxation of load under this maximum test load.
- (e) Recovery of the deformation after removal of all loads should be at least 80% of the total deformation at the maximum test load, and the tested anchor should not show any signs of separation, plastic deformation or deleterious effect.

Reference may be made to BS 5080 Parts 1 & 2 for the testing procedures for drilled-in anchors including apparatus set-up, load application and results presentation.

Annex B: List of International Standards

British Standards	Title
BS 146:2002	Specification for blastfurnace cements with strength properties outside the scope of BS EN 197-1
BS 812-103.1	Testing aggregates. Method for determination of particle size distribution. Sieve tests
BS 812-105.1:1989 (Replace BS 812:Section 105.1)	Testing aggregates. Methods for determination of particle shape. Flakiness index
BS 812-105.2	Testing aggregates. Methods for determination of particle shape. Elongation index of coarse aggregate
BS 812-110 (Replace BS 812:Part 3)	Testing aggregates. Methods for determination of aggregate crushing value (ACV)
BS 812-111 (Replace BS 812:Part 3)	Testing aggregates. Methods for determination of ten per cent fines value (TFV)
BS 812-112 (Replace BS 812:Part 3)	Testing aggregates. Method for determination of aggregate impact value (AIV)
BS 812-113 (Replace BS 812:Part 3)	Testing aggregates. Method for determination of aggregate abrasion value (AAV)
BS 812-114 (Replace BS 812:Part 3)	Testing aggregates. Method for determination of the polished-stone value
BS 812-117 (Replace BS 812:Part 4)	Testing aggregates. Method for determination of water-soluble chloride salts
BS 1881:Part 124	Testing concrete. Methods for analysis of hardened concrete
BS 1881-131:1998 (Partially replace BS 4550-3.4)	Testing concrete. Methods for testing cement in a reference concrete
BS 3148	Methods of test for water for making concrete (including notes on the suitability of the water)
BS 3892-1:1997 (Replace BS 3892:Part 1:1982*)	Pulverised-fuel ash. Specification for pulverised-fuel ash for use with Portland cement
BS 4035	Specification for linear measuring instruments for use on building and civil engineering constructional works. Steel measuring tapes, steel bands and retractable steel pocket rules
BS 4449	Steel for the reinforcement of concrete. Weldable reinforcing steel. Bar, coil and decoiled product. Specification
BS 4482	Steel wire for the reinforcement of concrete products. Specification
BS 4483	Steel fabric for the reinforcement of concrete. Specification
BS 4484-1	Specification for measuring instruments for constructional works. Metric graduation and figuring of instruments for linear measurement
BS 4550-3.1	Methods of testing cement. Physical tests. Introduction
BS 4550-3.4 (BS 4550:Part 3:Section 3.4:1978)	Methods of testing cement. Physical tests. Strength tests
BS 4550-3.8	Methods of testing cement. Physical tests. Test for heat of hydration
BS 5080-1	Structural fixings in concrete and masonry. Method of test for tensile loading
BS 5080-2	Structural fixings in concrete and masonry. Method for determination of resistance to loading in shear
BS 5606	Guide to accuracy in building
BS 5655-6 (Replace BS 5655:Part 6)	Lifts and service lifts. Code of practice for the selection and installation of new lifts
BS 5975	Code of practice for falsework

BS 6089	Guide to assessment of concrete strength in existing structures
BS 6699	Specification for ground granulated blastfurnace slag for use with Portland cement
BS 7123	Specification for metal arc welding of steel for concrete reinforcement
BS 7973-1	Spacers and chairs for steel reinforcement and their specification. Product performance requirements
BS 7973-2	Spacers and chairs for steel reinforcement and their specification. Fixing and application of spacers and chairs and tying of reinforcement
BS 8007	Code of practice for design of concrete structures for retaining aqueous liquids
BS 8102:1990	Code of practice for protection of structures against water from the ground
BS 8110:Part 1:1985	Structural use of concrete: Code of practice for design and construction
BS 8500-1 (Replace BS 1926 & 5328)	Concrete. Complementary British Standard to BS EN 206-1. Method of specifying and guidance for the specifier
BS 8500-2:2002 (Replace BS 1926 & 5328)	Concrete. Complementary British Standard to BS EN 206-1. Specification for constituent materials and concrete
BS 8666	Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete. Specification
BS EN 196-1 (Partially replace BS 4550-3.4)	Methods of testing cement. Determination of strength
BS EN 196-2 (Replace BS 4550:Part 2)	Methods of testing cement. Chemical analysis of cement
BS EN 196-3 (Replace BS 4550-3.5, 3.6 & 3.7)	Methods of testing cement. Determination of setting time and soundness
BS EN 196-5 (Replace BS 4550:Part 2)	Methods of testing cement. Pozzolanicity test for pozzolanic cements
BS EN 196-6 (Replace BS 4550-3.2 & 3.3)	Methods of testing cement. Determination of fineness
BS EN 196-7 (Replace BS 4550:Part 1)	Methods of testing cement. Methods of taking and preparing samples of cement
BS EN 197-1 (Replace BS 12*, 6588 & 7583)	Cement. Composition, specifications and conformity criteria for low heat common cements
BS EN 197-4:2004 (Replace BS 146:2002)	Cement. Composition, specifications and conformity criteria for low early strength blastfurnace cements
BS EN 206-1:2000 (Replace BS 1926 & 5328)	Concrete. Specification, performance, production and conformity
BS EN 480-1 (Replace BS 5075*)	Admixtures for concrete, mortar and grout. Test methods. Reference concrete and reference mortar for testing
BS EN 480-2 (Replace BS 5075*)	Admixtures for concrete, mortar and grout. Test methods. Determination of setting time
BS EN 480-4 (Replace BS 5075*)	Admixtures for concrete, mortar and grout. Test methods. Determination of bleeding of concrete
BS EN 480-5 (Replace BS 5075*)	Admixtures for concrete, mortar and grout. Test methods. Determination of capillary absorption
BS EN 480-6 (Replace BS 5075*)	Admixtures for concrete, mortar and grout. Test methods. Infrared analysis
BS EN 480-8 (Replace BS 5075*)	Admixtures for concrete, mortar and grout. Test methods. Determination of the conventional dry material content
BS EN 480-10 (Replace BS 5075*)	Admixtures for concrete, mortar and grout. Test methods. Determination of water soluble chloride content
BS EN 480-11 (Replace BS 5075*)	Admixtures for concrete, mortar and grout. Test methods. Determination of air void characteristics in hardened concrete

BS EN 480-12 (Replace BS 5075*)	Admixtures for concrete, mortar and grout. Test methods. Determination of the alkali content of admixtures
BS EN 933-1 (Replace BS 812-103.1)	Tests for geometrical properties of aggregates. Determination of particle size distribution. Sieving method
BS EN 934-2 (Replace BS 5075*)	Admixtures for concrete, mortar and grout. Concrete admixtures. Definitions, requirements, conformity, marking and labelling
BS EN 934-6 (Replace BS 5075*)	Admixtures for concrete, mortar and grout. Sampling, conformity control and evaluation of conformity
BS EN 1008 (Replace BS 3148*)	Mixing water for concrete. Specification for sampling, testing and assessing the suitability of water, including water recovered from processes in the concrete industry, as mixing water for concrete
BS EN 12350-2 (Replace BS 1881-102)	Testing fresh concrete. Slump test
BS EN 12620 (Replace BS 882*)	Aggregates for concrete
BS EN 13139 (Replace BS 1199 and 1200)	Aggregates for mortar
BS EN 14188-1 (Replace BS 2499-1)	Joint fillers and sealants. Specifications for hot applied sealants
BS EN 15167-1	Ground granulated blast furnace slag for use in concrete, mortar and grout. Definitions, specifications and conformity criteria
BS EN ISO 1461	Hot dip galvanized coatings on fabricated iron and steel articles - Specifications and test methods
BS EN ISO 9000	Quality management systems. Fundamentals and vocabulary
BS EN ISO 9001	Quality management systems. Requirements
BS EN ISO 15630-1	Steel for the reinforcement and prestressing of concrete - Test methods - Part 1: Reinforcing bars, wire rod and wires
BS EN ISO 15630-2	Steel for the reinforcement and prestressing of concrete - Test methods - Part 2: Welded fabric
International Organization for Standardization	Title
ISO 1920-2:2005	Testing of concrete - Part 2: Properties of fresh concrete
Canadian Standards	Title
CAN/CSA-A23.5-98	Supplementary Cementing Materials
American Standards	Title
ASTM C1240-05	Standard Specification for Silica Fume Used in Cementitious Mixtures
ASTM C512-02	Standard Test Method for Creep of Concrete in Compression
American Public Health Association (APHA)	Standard Methods for the Examination of Water and Wastewater, Sections 3500-K and 3500-Na
RILEM Standards	Title
RILEM AAR-2	Accelerated test for the alkali-reactivity potential of concrete aggregates - The ultra-accelerated mortar-bar test

Note: The withdrawn BS marked with asterisk * denotes which remains acceptable by Buildings Department according to the Code of Practice for Structural Use of Concrete 2004.