SECTION 5: CONCRETE AND STRUCTURES

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SECTION 5.01 CONCRETE MIXES AND TESTING

5.01.1 SCOPE

The works covered in this Section consists of the specifications for concrete materials including sampling, testing and storage of such materials, concrete strength requirements, concrete testing procedures and requirements and job mixes.

5.01.2 MATERIALS

A. Cement

A.1 Cement shall be Portland cement, originating from manufacturers approved by the Engineer and shall comply with BS EN 197-1:2000 for Ordinary Portland Cement and with BS 4027:1996 for Sulphate Resisting Portland Cement.

A.2 Only one type or brand of cement shall be used in any one structural member. Mixing of types or brands shall not be permitted.

A.3 All cement shall be subject to approval and shipments of cement shall be accompanied by a manufacturer's Certificate of Guarantee and a laboratory test certificate. Approval of any cement sample shall not relieve the Contractor of the responsibility to fabricate concrete of the specified quality and strength.

A.4 When factory or field tests subsequent to original approval tests show that the cement no longer complies with the Specifications, the entire consignment from which the sample was taken shall be rejected and the Contractor shall immediately remove the rejected material from the Site and replace it with cement meeting the required specifications.

A.5 Whenever low alkali cement is specified, the total alkali content, expressed as the sodium oxide equivalent, shall not exceed 0.6% by weight. Approval of any cement sample shall not relieve the Contractor of the responsibility to fabricate concrete of the specified quality and strength.

A.6 If local test certificates are not available the Contractor shall obtain from each proposed manufacturer a typical sample of cement which shall be fully and independently tested in accordance with the appropriate standard and the results submitted for approval. Primary and secondary sources of the required cement shall be given. All costs associated with the testing shall be allowed for by the Contractor.

A.7 Details shall also be submitted of the manufacturer's name, the address of the source of production, the manufacturer's description of the cement type and brand name and the standards to which compliance is guaranteed.

A.8 Average values and corresponding maximum and minimum values of the following cement composition and properties shall be submitted, covering a continuous production period of at least 6 months and ending not earlier than 3 months before submission of the data. The Contractor shall state if any material or production process changes have been made since the end of the above period; if any are proposed details shall be provided.

Composition	**Properties**	
Insoluble residue	Lime saturation factor (LSF)	
Silica (SIO_2)	Alumina-iron ratio (A/F)	
Alumina (AL_20_3)	Tri-calcium aluminate (Ca3A1)	
Total Iron ($Fe_2 O_3$)	Free lime in clinker (as CaO)	
Calcium (CaO)	Total acid solution alkalis	
Magnesium (MgO)	Heat of hydration	
Potassium ($K_2 O$)	- at 7 days	
Sodium (Na_2)	- at 28 days	
Sulphate (SO_3)	Fineness (m^2./kg)	
Sulphur (S)	Setting times	- Initial (min)
Chloride (Cl)		- Final (min)
Loss on ignition	Soundness (mm)	
	Compressive strength	- 3 days
		- 7 days
		- 28 days
		- 3 months

A.9 The requirements of item A.8 shall only be modified or dispensed with at the discretion of the Engineer and if such dispensation is given in writing.

A.10 The manufacturer's bulk average test certificate for each consignment of cement shall be submitted, showing the results for chemical composition and physical properties determined in accordance with the relevant standard. Samples shall be taken for each consignment of cement and tested as directed by the Engineer by an approved independent laboratory and at the Contractor’s expense.

A.11 Where bulk cement deliveries are proposed, the Contractor shall provide all information required by the Engineer concerning off-site storage and loading arrangements and facilities for the Engineer to inspect these arrangements for approval purposes shall be provided. Consignments shall be used in the order in which they are delivered.

A.12 Storage capacity shall be sufficient to meet the schedule of work so that continuous work is achieved. Cement shall be stored in moisture-proof storage sheds. Stale, caked, reclaimed or re-sacked cement shall not be used. The Contractor shall not store cement in areas subject to flooding.

A.13 Cement remaining in bulk storage at the mill for more than 6 months or cement stored in bags in local storage by the Contractor or a vendor for more than 3 months after shipment from the mill shall be retested before use and shall be rejected if it fails to meet any of the requirements of these specifications.

B. Aggregates

B.1 Proposed aggregate sources shall be examined by the Engineer who shall check the following:

- Name, location, grid reference, type of deposit, potential variability, methods of extraction.
- Methods and degree of control exercised over extraction.
- Processing methods, types of plant, number of processing stages, standards of maintenance and process control, producer's laboratory facilities and technical staffing.
- Stockpiling arrangements, loading and supply arrangements.
- Potential variations in end-products due to variations inherent in the deposit and in the existing methods of extraction, processing and stockpiling.
- Modifications to existing extraction, processing, storage and handling arrangements, and to supervision arrangements to reduce end-product variations.
- Requirements for supplementary processing on site.

B.2 The Contractor shall provide photographs of each of the proposed new sources and related production arrangements. The source photographs shall include low level aerial photographs and close-ups of working faces.

B.3 Aggregate deposits shall be sampled and tested in a systematic manner to assess their potential variability and to assist in determining appropriate methods of extraction and processing.

B.4 The deposit investigation and sampling programmes shall be relevant to each type of deposit and shall be devised and supervised by an experienced engineering geologist approved by the Engineer. The engineering geologist shall make a field reconnaissance of the potential deposit areas and the existing workings.

B.5 Each size of aggregate shall be sampled at the discharge points on the production plant (i.e. conveyors or hoppers, not stockpiles) at three well spaced intervals during the course of each of three consecutive production days; these samples shall be designated "production samples".

B.6 Samples shall be taken from producer's stockpiles of any materials with visible variations in physical characteristics or appearance and materials ready for loading. These samples shall be designated "stockpile samples".

B.7 All samples shall be taken by arrangement with and in the presence of the Engineer or his representative and shall be tested in accordance with these specifications

B.8 All samples shall split for independent testing by the Contractor and the Engineer. These samples shall be retained on site.

C. Testing Aggregates

C.1 Each production sample shall be tested for the following:

- Proportion of natural (uncrushed) material (% by weight) passing a 75mm sieve.
- Total acid soluble chloride content and total acid soluble sulphate content (% by weight).
- Flakiness and elongation indices.

C.2 Aggregates from all production sources shall be combined (by equal weight) to form composite production samples for each size of aggregate. The composite samples and the individual production samples shall be tested for the following: -

- Potential Reactivity tests for alkali-silicate and alkali-carbonate reactions: petrographic examination in accordance with BS 812-104:1994 or ASTM C295, rapid chemical method in accordance with ASTM C289 and rock expansion test in accordance with ASTM C586. If one or more of these tests are positive then the mortar prism test in accordance with ASTM C227 shall be carried out.
- Partial chemical analysis, including insoluble residue (ASTM D3042-84), chloride content, sulphate content and calculated approximate composition.
- ASTM Soundness Test C88, using a sodium sulphate solution, or ASTM Soundness Test C88, using a magnesium sulphate solution.
- Aggregate Impact Value by the Los Angeles test in accordance with BS EN 1097-2:1998 or AASHTO T96-83, ASTM C131-81 and ASTM C535-81.
- 10% Fines Value to BS EN 1097-2:1998 or BS 812-111:1990.
- Aggregate Abrasion Value to BS EN 1097-8:2000.
- Specific Gravities and Water Absorption to BS EN 1097-3:1998 or BS 812-2:1995.

C.3 Stockpile samples shall be examined and tested at frequencies determined by the Engineer.

C.4 The properties of the aggregates shall be such that the Drying Shrinkage of concrete prepared and tested in an approved laboratory in accordance with the United Kingdom Building Research Station Digest No. 35 (Second Series) shall not exceed 0.045 percent. The Initial Drying Shrinkage of all the proposed concrete mixes prepared and tested in an approved laboratory in accordance with BS EN 1367-4: 1988 shall not exceed 0.06 percent.

C.5 Aggregate for use in concrete or mortar that will be subject to wetting, exposure to a humid atmosphere or in contact with moist ground shall also be subject to the following conditions: -

- Aggregate shall not contain material that is deleteriously reactive with the alkalis in the cement or is present in the aggregates and mixing water or water in contact with the concrete, in amounts sufficient to cause excessive localized or general expansion of concrete or mortar.
- Dacite, Andesite, Rhyolites, Opal Cherts or Tuffs shall not be used in aggregates.
- Coarse and fine aggregates shall be tested for reactivity potential and shall satisfy the criteria given for innocuous aggregates in ASTM C 1260. The period of testing shall be a minimum of 26 weeks unless otherwise agreed by the Engineer.

D. Fine Aggregates

D.1 Fine concrete aggregates shall conform to AASHTO M6 and shall consist of natural sand or crushed rock having hard and durable particles or, if approved by the Engineer, other inert materials having similar characteristics. 100% of the fine aggregate shall pass the 9.5 mm sieve and 2% to 10% shall pass the 0.15 mm sieve. The fine aggregate shall not contain harmful materials including iron pyrites, coal, mica, shale or similar laminated materials, flat or elongated particles or any materials which may adversely affect the reinforcement or the strength, durability and texture of the concrete.

D.2 The Contractor shall wash the fine aggregates to remove deleterious substances or for colour consistency. Washing shall be carried out using fresh water. The water shall be replaced regularly to minimise the chloride and/or sulphate content.

D.3 The total acid soluble sulphate content (BS EN 1744-1:1998 or BS 812-118 1988) of fine aggregate, expressed as sulphur trioxide (SO_3), shall not exceed 0.40% by dry weight (BS EN 1744-1:1998 or BS 812-117:1988). The total acid soluble chloride content, expressed as sodium chloride (NaCl), shall not exceed 0.10% by dry weight of fine aggregate. The following additional requirements shall apply to the concrete mix:

- Total sulphate content (as SO_3) of any mix, excluding that present in the cement but including any present in the other materials, shall not exceed 2.5% by weight of cement in the mix.
- Total chloride content (as NaCl) of any mix, including any chloride present in the other materials and in the mix water, shall not exceed 0.35% by weight of cement in the mix.

D.4 Fine aggregate shall meet the following additional requirements:

- Fineness modulus, AASHTO M6: ±0.20% of approved value which shall be not greater than 3.1 or less than 2.3. Sieve analysis to AASHTO T27.
- Sodium or magnesium sulphate soundness AASHTO T104: max 12%, 18% loss respectively.
- Content of clay lumps and friable particles, AASHTO T112-82: 3% max.
- Sand equivalent AASHTO T176: min 75%.
- Coal and lignite, AASHTO T113-82: 0.5% Max.
- Organic impurities AASHTO T21-81: not darker than standard colour.

D.5 The amount of hollow shells likely to form voids and present in material retained on a 2.36 mm sieve determined by direct visual separation, shall not exceed 3% by weight of the entire sample.

D.6 When sampled and tested in accordance with the appropriate sections of BS 812 (using test sieves in accordance with BS 410-1:2000 and 410-2:2000) the grading of fine aggregates shall be within the limits of the grading zones given in BS-EN 12620:2002. The fine aggregate shall be described as a fine aggregate of the grading zone into which it falls.

D.7 If the fineness modulus varies by more than 0.2 from the value assumed in the concrete mix design, the use of such fine aggregate shall be discontinued until suitable adjustments can be made to the mix proportions to compensate for the difference in gradation.

E. Coarse Aggregates

E.1 Coarse concrete aggregates shall conform to AASHTO M80 and shall consist of gravel, crushed gravel or crushed stone free from coatings of clay or other deleterious substances. It shall not contain harmful materials which can attack the reinforcement or adversely affect the strength and durability of the concrete. Coarse aggregate shall be washed to remove deleterious substances or for consistency of colour in the concrete.

E.2 The total acid soluble sulphate content (BS EN 1744-1: 1998) of coarse aggregate expressed as sulphur trioxide (SO_3) shall not exceed 0.40% by weight. The total acid soluble chloride contents of coarse aggregates, expressed as sodium chloride (NaCl), shall not exceed 0.05% by weight. These limits are also subject to the following requirements:

- The total sulphate content (as SO_3) of any mix, excluding that present in the cement but including any present in the other materials, shall not exceed 2.5% by weight of cement in the mix.
- The total chloride content (as NaCl) of any mix, including any chloride present in the other materials and the mix water, shall not exceed 0.35% by weight of cement in the mix.

E.3 Coarse aggregate shall also meet the following requirements:

- Sodium or magnesium sulphate soundness AASHTO T104: 5 cycles: max 12%, 18% loss respectively.
- Abrasion: in accordance with AASHTO T96 Max 40% loss.
- Content of clay lumps and friable particles: AASHTO T112-81: max 1% by weight.
- Soft fragments and shale: AASHTO M80: max 5% by weight.
- Flakiness index: BS EN 933-3: 1997: 30% max.
- Elongation index, BS 812-105.2:1990: 30% max.
- Coal and Lignite: AASHTO T113-82: 0.5% max.

E.4 The grading of coarse aggregate shall comply with AASHTO M43.

E.5 The coarse concrete aggregate, when tested according to AASHTO T27, shall meet the following gradation requirements and shall be graded within the limits stated in Table 5.1.1.

TABLE 5.1.1: LIMITS OF GRADATION FOR COARSE AGGREGATES

AASHTO Sieve Size	mm	Percent Passing by Weight for					
		Grading I	Grading II	Grading III	Grading IV	Grading V	Grading VI
3'	75	100	-	-	-	-	-
2 1/2"	63	-	100	-	-	-	-
2"	50	90-95	95-100	100	-	-	-
1 1/2"	37.50	-	-	95-100	100	-	-
1"	25.0	30-65	35-70	-	95-100	100	-
3/4"	19.0	-	-	35-70	-	95-100	100
1/2"	12.5	10-30	10-30	-	25-60	-	90-100
3/8"	9.5	-	-	10-30	-	20-55	40-70
No. 4	4.75	0-5	0-5	0-5	0-10	0-10	0-15
No. 8	2.36	-	-	-	0-5	0-5	0-5
No. 200	0.075	0-1	0-1	0-1	0-1	0-1	0-1

E.6 The type of grading for coarse concrete aggregates shall depend on the maximum particle size, which shall be no larger than one-fifth (1/5) of the narrowest dimension between sides of forms, nor larger than two-thirds (2/3) of the minimum clear spacing between reinforcing bars, whichever is least.

E.7 Before batching, all types of coarse aggregate shall be separated into fractions having uniform gradings.

F. Combined Aggregates

F.1 Combined aggregate comprises of a mixture of coarse and fine aggregates. They shall be used only in proportions agreed with the Engineer.

F.2 Materials passing the No. 200 (0.075 mm) sieve shall not exceed 3% by weight of the combined aggregate.

F.3 The combined concrete aggregate gradation shall be as specified or as directed by the Engineer. Grading 7 of Table 5.1.2 shall be used for kerbs, handrails, parapets, posts and other similar sections or members with reinforcement spacing too close to permit proper placement and consolidation of the concrete.

F.4 Changes from one gradation to another shall not be made during the progress of work unless approved by the Engineer.

F.5 For the proportion of each fraction of coarse aggregate and for fine and coarse aggregate, the combined gradings in Table 5.1.2 shall be used for the mix proportion design.

TABLE 5.1.2: LIMITS OF GRADATION FOR COMBINED AGGREGATES

AASHTO Sieve Size	mm	Combined Aggregate Percent Passing by Weight for						
		Grading 1	Grading 2	Grading 3	Grading 4	Grading 5	Grading 6	Grading 7
3"	75	100	-	-	-	-	-	-
2 1/2"	63	88-95	100	-	-	-	-	-
2"	50	78-90	88-95	100	100	-	-	-
1 1/2"	37.50	66-81	74-86	80-92	93-98	100	-	-
1"	25.0	51-70	56-75	63-80	70-88	87-96	100	-
3/4"	19.0	43-62	47-67	52-72	60-79	73-86	80-96	100
1/2"	12.5	32-53	36-58	41-60	47-66	57-74	61-80	73-86
3/8"	9.5	27-48	30-53	36-54	40-60	48-68	52-72	61-79
No. 4	4.75	19-38	22-42	23-43	28-49	34-55	38-56	43-64
No. 8	2.36	9-27	10-29	12-30	16-36	24-40	25-41	26-46
No. 16	1.18	4-19	5-21	6-22	7-25	9-28	11-29	13-33
No. 30	0.600	3-15	4-17	4-19	5-21	7-23	8-24	10-28
No. 50	0.300	2-11	2-13	2-14	2-15	4-17	5-19	5-21
No.100	0.150	1-7	1-8	1-8	1-9	2-10	2-11	2-12
No.200	0.075	0-3	0-3	0-3	0-3	0-3	0-3	0-3

G. Site Storage of Aggregates

G.1 Adequate stocks of tested and approved aggregates shall be maintained on site and the capacity of the storage bins for each type and grading of aggregate shall be sufficient to hold the respective quantities required for the maximum amount of concrete which the Contractor is obliged or intends to pour in any continuous operation in one day. The maximum height of aggregate stockpiles shall be 1.50 metres. Different grades of aggregates shall be separated by concrete block walls.

G.2 Dense concrete or bituminous slabs shall be laid with sufficient falls to cover all aggregate stockpile areas or bins and shall extend to cover all surrounding areas where aggregates are likely to be discharged or handled. These areas shall be swept and kept clean at all times to ensure that the aggregates are not contaminated by the adjacent ground through trafficking or otherwise and shall be constructed with adequate drainage for surplus water.

G.3 Windbreaks shall be provided where aggregates might suffer excessive contamination from windblown materials. During periods of heavy rain the bins or stockpiles shall be covered by tarpaulins.

H. Rejection of Aggregates

H.1 The Engineer shall reject any stockpiled material that has an excess build-up of fines.

H.2 Aggregates suffering from segregation or contamination during processing, handling at source, transportation to the site, stockpiling, handling on site or otherwise not complying with the requirements of the Specification shall be rejected and removed promptly from site regardless of any prior approval of the source.

I. Washing and Processing Aggregate

The Contractor shall carry out on site supplementary processing or effective washing of coarse and fine aggregates as necessary to comply with all requirements of the Specification.

J. Water

J.1 All sources of water, whether for mixing or curing of concrete or compaction of backfill around the concrete structures shall be approved by the Engineer. If during construction water from a particular approved source becomes unsuitable for purpose, the Contractor shall provide satisfactory water from other approved sources.

J.2 Water shall be free from injurious quantities of oil, alkali, vegetable matter and salt. The water shall be reasonably clear and shall contain not more than one quarter (0.25) percent solids by weight. Water shall comply with the requirements of BS EN1008:2002. If the specific conductance is less than 1500 micro ohms per centimetre, the total solids content requirement shall be waived, if agreed with the Engineer.

J.3 Non-potable water shall only be used when potable water is not available and provided the impurities do not exceed the values given in Table 5.1.3.

J.4 The water used in the mix design shall be from a source approved by the Engineer for site use.

J.5 Water used concrete containing or in contact with aluminium fittings or fixtures shall not contain chloride ions.

TABLE 5.1.3: MAXIMUM PERMITTED IMPURITIES IN NON-POTABLE WATER

Impurity	Max. Concentration (ppm)	Method
Chloride as (Cl-) a) Prestressed concrete or concrete in bridge decks b) Other reinforced concrete - in a moist environment, or - containing aluminium anchorages or reinforcement, or - permanent galvanized metal formwork	500 1000	ASTM D512
Sulphates as SO_4	300	ASTM D516
Alkalis as $Na_2O+0.658\ K_2O$	600	AASHTO T-26
Total solids	5000	

K. Admixtures

K.1 The quantity and method of using admixtures shall be in accordance with the manufacturer's recommendations and in all cases shall be subject to the approval of the Engineer.

K.2 The Contractor shall provide the following information for the Engineer's approval:

- The quantity to be used in kilograms per kilogram of cement and in kilograms per cubic metre of concrete.
- The detrimental effects caused by adding a greater or lesser quantity in kilograms per cubic meter of concrete.
- The chemical name(s) of the main active ingredient(s).
- Whether the admixture leads to the entraining of air.

K.3 The Contractor shall demonstrate the suitability of an admixture by means of trial mixes.

K.4 The use of calcium chloride in any form is prohibited.

L. High Workability Admixtures

L.1 Superplasticising agents shall be used when detailed on the Drawings or directed by the Engineer. The superplasticiser shall be stored and used strictly in accordance with the manufacturer's instructions and shall be fully compatible with all proposed concrete mix constituents. The optimum dosage of the additive shall be determined by site and laboratory trials to the Engineer's approval. The Contractor shall submit to the Engineer full details of his proposed mix design, which shall ensure that the minimum strength requirements as specified for the particular use of the concrete are achieved. Only when the Engineer has approved the proposed mix design shall such a mix be used in the Works.

L.2 The Contractor's mixing and transporting plant shall include accurate metering equipment for the measurement of superplasticising agents so that additives may be introduced immediately before placing.

L.3 The Contractor's rates for concrete listed in the Bill of Quantities shall include for the use of superplasticisers. The rate shall be inclusive for compliance with the Specification together with all necessary testing and trials for concrete containing superplasticisers.

5.01.3 DEFINITIONS

A. Crushing Strength

The crushing strength of a test cylinder prepared in accordance with AASHTO T23 and AASHTO T126 or standard cubes prepared with accordance to BS specifications.

B. Average Strength

The mean of the crushing strengths of specimens taken from a sample of concrete.

C. Characteristic Strength

The value of the crushing strength below which 5% of the population of all possible strength measurements of the specified concrete are expected to fall.

D. Fresh Concrete

Concrete during the first two hours after the addition of water to the mix.

E. Batch

The quantity of concrete mixed in one cycle of operations of a batch mixer, the quantity of concrete conveyed ready-mixed in a vehicle or the quantity discharged during one minute from a continuous mixer.

F. Sample

A quantity of concrete taken from a batch whose properties are to be determined.

G. Regular Sampling

The sampling of concrete nominally of the same mix received regularly from the same source.

H. Specimen

Cylinder or cube taken from a sample for testing.

5.01.4 CONCRETE STRENGTH REQUIREMENTS

A. Design Mixes

A.1 Mixes for the classes of concrete (shown in Table 5.1.4) shall be designed by the Contractor. The quantity of water used shall not exceed that required to produce a concrete with sufficient workability to be placed and compacted in the particular location required. Unless otherwise approved by the Engineer, the mix designs shall use continuously graded aggregates. All mix designs shall be submitted to the Engineer for approval.

A.2 The Cement content in any mix shall not exceed 450 kg/m^3.

A.3 The 7-day compressive strength of any mix shall not be less than 75% of the specified 28 day strength. If the 7-day result is below the 75% requirement, the Contractor shall postpone works related to the suspected concrete until the 28 days results are available, unless otherwise agreed to by the Engineer, at the Contractor's risk.

A.4 The ultimate compressive strength of concrete shall be determined on test specimens obtained as follows:

Either: Test cylinders prepared and tested in accordance with AASHTO T23 and AASHTO T126. Six inch by twelve inch cylinders shall be used for all compression tests.

Or: Cubes prepared and tested in accordance with BS 1881.

TABLE 5.1.4:CONCRETE CLASS AND DESIGN MIXES

Class of Concrete	Cylinder Works Strength at 28 days: Kg/cm^2	Equivalent Works Cube Strength @ 28 days: Kg/cm^2	Maximum Size of Aggregate: mm	Minimum Cement Content Kg/m^3
110/25 (Blinding)	110	140	25	220
140/25	140	180	25	250
170/60	170	210	60	275
210/50	210	260	50	300
210/25	210	260	25	325
210/20 (B20)	210	260	20	325
250/20 (B25)	250	310	20	350
250/30	250	310	30	350
310/20	310	385	20	375
360/20	360	450	20	425
400/20	400	500	20	425
500/20	500	625	20	425
600/20	600	750	20	425

B. Nominal Concrete Mix

B.1 General

Concrete for use as backfilling for structural excavation shall be either no-fines concrete or cyclopean concrete as directed by the Engineer. The cement: aggregate ratio of such mixes shall be not greater than 1:15 and the minimum cylinder strength at 28 days shall be not less than 50 Kg/cm^2 or minimum 28-day cube strength shall no be less than 60 Kg/cm^2.

B.2 No-Fines Concrete

No-fines concrete shall comply with the grading in Table 5.1.5 and shall be mixed and laid in general conformity with this Section 5.01.

B.3 Cyclopean Concrete

Plums used in cyclopean concrete shall consist of non-reactive broken stone spalls or boulders ranging in size from 200mm to 300mm. They shall be free from sharp or angular edges and shall not form more than 30% of the total volume of concrete. They shall be evenly graded and shall be soaked in water prior to incorporation in the mix. Plums shall be evenly distributed in the concrete mix with a minimum cover of 100mm. The compressive strength the rock plums shall be at least 100 Kg / cm^2 to ASTM D2938. The concrete used in cyclopean concrete shall be Class B20

TABLE 5.1.5: GRADING FOR NO-FINES CONCRETE

Sieve Size	% by Dry Weight Passing
90 mm	100
40 mm	85-100
20 mm	0 - 20
10 mm	0 - 5

C. Compliance with Strength Requirements

C.1 General. Cylinders or cubes from concrete as mixed for the Work will be tested in accordance with AASHTO T22 or BS 1881, as appropriate, after both seven and twenty eight days. Test specimens shall be made and cured in accordance with AASHTO T23 or BS 1881. These specimens will be the basis for acceptance of the concrete in the structure.

C.2 Preliminary Tests

C.2.1 Prior to the commencement of any concreting work and subsequently, whenever a change in the mix is intended, preliminary tests shall be carried out. From each of three samples of materials, a trial mix shall be made. For each class of concrete, the trial mixes shall represent at least two different water- cement ratios. From each trial mix, six cylinders (or cubes) shall be made, three for testing at 7 days, and three for testing at 28 days. The average strength of the cylinders (or cubes) tested for each sample shall be taken as the preliminary cylinder (or cube) strength of the mix.

C.2.2 The Engineer will require the preliminary test to be repeated if the difference in strength between the greatest and the least strength is more than 20 per cent of the average.

C.2.3 The water /cement ratio and slump adopted in the preliminary tests for each class of concrete shall be used in the works concrete. It shall be such that, if selected for use at the Site, the concrete can be worked readily into the corners and angles of the forms and around the reinforcement without permitting the materials to segregate or free water to collect on the surface.

C.2.4 Preliminary tests shall have these minimum ultimate strengths given in Table 5.1.6.

C.3 Works Tests

C.3.1 During the first four days of the commencement of concreting with any particular mix, two sets of six works cylinders (or cubes) in each set shall be made each day. Three cylinders (or cubes) from each set shall be tested at 7 days, and 3 at 28 days. The above works tests shall be carried out for each class of concrete. Subsequently, the frequency of making sets of test cylinders (or cubes) and the number in each shall be as directed by the Engineer.

TABLE 5.1.6: PRELIMINARY TESTS FOR STRENGTH

Class of Concrete	Cylinder Strength (Kg/cm^2)	Equivalent Cube Strength (Kg/cm^2)
110/25	170	210
140/25	210	260
170/60	240	300
210/50	290	360
210/25	290	360
210/20	290	360
250/20	325	400
250/30	325	400
270/20	350	430
310/20	395	490
360/20	440	550
400/20	480	600
450/20	520	650

C.3.2 The cylinders (or cubes) shall be cured in the same conditions and environment as the members they represent. The cylinder (or cube) strength shall be accepted as complying with the specified requirement for work cylinder (or cube) strength if none of the compressive strengths of the cylinders (or cubes) falls below the minimum strengths given in Table 5.1.4 or if the average strength is not less than the specified minimum works cylinder (or cube) strength and the difference between the greatest and least cylinder (or cube) strength is not more than 20 per cent of the average.

C.3.3 For the concrete batch to be accepted, not more than 5 per cent of works cylinder (or cube) strengths shall fall below the specified strength. For this requirement to be achieved, the mean strengths of works cylinders (or cubes) less 1.64 times the standard deviation should not be less than the required strength. This calculation shall be made for both 7 and 28 day cylinder (or cube) tests as soon as 24 cylinders (or cubes) have been tested at each age. Thereafter, it shall be repeated as further test results become available at a frequency determined by the Engineer. The number of cylinders (or cubes) considered in each calculation shall be the total number of cylinders (or cubes) of the mix in question tested from the commencement of the Works.

C.3.4 Cores shall be taken in accordance with ACI 318 and tested in accordance with AASHTO T24. Load testing shall be carried out in accordance with ACI 318, chapter 20. The Contractor shall hire an authorized independent laboratory to carry out such tests at his own expense.

C.4 The Engineer shall instruct the preparation of additional test cylinders or cubes if necessary to ascertain the effectiveness of the methods by which the structure is being cured and also to determine when the structure may be placed in service. These cylinders or cubes shall be cured in the field in the same manner as the concrete placed in the structure, and the Contractor shall protect the cylinders or cubes from all damage.

C.5 The Contractor shall take every precaution to prevent damage to the test cylinders or cubes during handling, transporting and storing. He shall be held solely responsible for any test failure caused by improper handing, transportation or any other cause which may be detrimental to the test cylinder or cube.

C.6 In order that the test cylinders or cubes are transported from the field to the laboratory undamaged, the Contractor shall provide a minimum of two approved boxes (one for the Contractor's use and the other for the Engineer's use). Boxes shall be of such size to receive a minimum of six test cylinders or cubes and sufficient space for sawdust packing around all surfaces of the cylinders or cubes. Boxes shall be approved by the Engineer. The Contractor shall, when directed by the Engineer, provide as many additional boxes as may be required by the remoteness and/or magnitude of the concrete work.

C.7 When test cylinders or cubes fail to meet the minimum strength requirements, the Engineer shall instruct core samples to be taken to determine the acceptability of structural elements. The Contractor shall, at his own expense, furnish all equipment required for such core sampling.

5.01.5 COMPOSITION OF CONCRETE

A. Mix Proportions

A.1 The Contractor shall consult with the Engineer on mix proportions at least forty-five (45) days prior to the commencement of concrete work. The actual mix proportions of cement, aggregates, and water shall be determined by the Contractor.

A.2 The Contractor shall, in the presence of the Engineer, prepare trial-mixes for each class of concrete required for the project, made with the approved materials to be used in the Works. The proportions of the trial-mixes shall be such as to produce a dense mixture containing the specified minimum cement content and meeting the workability and the preliminary test strength requirements specified for the designated class of concrete.

A.3 If the materials supplied by the Contractor are of such a nature or are so graded that proportions based on minimum cement content cannot be used without exceeding the maximum allowable water content, the use of admixtures to maintain the water content within the specified limit shall be permitted, subject to the approval of the Engineer. At all times the concrete mix shall satisfy the durability requirements by satisfying the minimum and maximum specified cement and water contents.

A.4 The Engineer shall review the Contractor's trial- mixes against the seven and twenty eight day test cylinder or cube strength results and determine which of the trial-mixes shall be used. If none of the trial-mixes for a particular class of concrete meets the specification, the Engineer shall direct the Contractor to prepare additional trial-mixes. No class of concrete shall be prepared or placed until its job-mix proportions have been approved by the Engineer.

A.5 The approval of the job-mix proportions by the Engineer or his assistance to the Contractor in establishing those proportions, does not relieve the Contractor of the responsibility of producing concrete which meets the specified requirements.

A.6 All costs connected with the preparation of trial-mixes and the design of the job-mixes shall be borne by the Contractor.

B. Design Limits

The following parameters shall be designated by the Engineer within the limits of the specifications:

- The minimum cement content in sacks per cubic metre of concrete.
- The maximum allowable water content in litres per sack of cement, or equivalent units, including surface moisture, but excluding water absorbed by the aggregates.
- The ratio of coarse and fine aggregates.
- Slump or slumps designated at the point of delivery.

C. Changes to Mix Design

C.1 Changes in mix proportions requested by the Contractor to previously approved mix designs shall only be made following approval by the Engineer.

C.2 If, in the opinion of the Engineer, cement is being lost due to windy conditions, the Contractor shall add additional amounts of cement as directed by the Engineer. No additional payment shall be made for the additional cement.

C.3 The Engineer shall instruct the Contractor to change the proportions of any particular mix if conditions warrant such changes to produce satisfactory results. Any such change shall be made within the limits of the specifications at no additional cost to the Contract.

C.4 When, in the opinion of the Engineer, additional protection against concrete deterioration due to a salty environment is necessary, he shall instruct the Contractor to increase the cement content of a particular mix by ten per cent over and above that cement content used in the approved trial-mix design for a non-salty environment, irrespective of the use of water barriers. The water content shall be adjusted accordingly to obtain a dense workable mix. All bridge footings and column lengths to the first construction joint above the ground surface for the entire project are subject to this increased cement content. No additional payment shall be made for the increase in cement content.

C.5 Failure of the mix to meet specifications determined by the Engineer under items A and B in this sub-section will be grounds for the Engineer to reject the concrete.

C.6 Mortar for laying stone for grouted stone riprap, grouted stone wash checks or grouted stone ditch lining shall be composed of one part of Ordinary Portland Cement and three parts of fine aggregate by volume with water added to make a workable mix. The amount of water added to the mix shall be approved by the Engineer.

C.7 Aggregates for masonry mortar shall conform to AASHTO M45.

C.8 Portland cement shall conform to AASHTO M85, Type I, II or III.

5.01.6 REQUIREMENTS FOR COMBINING MATERIALS

A. Measurement of Materials in Mix

A.1 **Cement** shall be measured in bulk or as packed by the manufacturer (in 50 kilogram sacks). Measurement shall be accurate to within (+/-) 3.0 %.

A.2 **Water:** The mixing water shall be measured by weight or by volume. In either case the measurement shall be accurate to within (+/-) 2.0 %.

A.3 **Aggregates:** The aggregates shall be measured by weight. The measurement shall be accurate to within (+/-) 2.0% for fine and coarse aggregates.

A.4 **Additives:** Additives shall be measured by volume if in liquid form and by weights if solid. The measurement shall be accurate to within (+/-) 3.0 %.

B. Assembly and Handling of Materials

B.1 **Assembly:** Aggregates shall be delivered and stored in such quantities that sufficient material approved by the Engineer is available to complete any continuous pour necessary for structures. The batching site shall be of adequate size to permit the stockpiling of sufficient unsegregated material of uniform moisture content to ensure continuous operation. The Contractor shall take measures to ensure that no foreign matter or materials capable of changing the desired proportions are included n the mix. If two or more sizes or types of coarse or fine aggregates are used on the same Project, only one size or type of each aggregate may be used on a continuous pour.

B.2 Stockpiling of Aggregates: All aggregates shall be stockpiled before use in order to prevent segregation of material, to ensure a uniform moisture content and to provide uniform conditions for proportioning plant control. The use of equipment or methods of handling aggregates which results in the degradation or segregation of the aggregates is strictly prohibited. Bulldozers with metal tracks shall not be used on coarse aggregate stockpiles and all equipment used for handling aggregates shall be approved by the Engineer. Methods of stockpiling aggregates shall be approved by the Engineer. Segregation shall be prevented by making no layer higher than 1.5 metres and, if two or more layers are required, each successive layer shall not be allowed to "cone" down over the next lower layer. Aggregates shall not be stockpiled against the supports of proportioning hoppers or weighing devices.

B.3 Segregation: Segregated aggregates shall not be used until they have been thoroughly remixed and the resultant pile is of uniform gradation at any point from which a representative sample is taken. The Contractor shall remix aggregate piles when so ordered by the Engineer.

B.4 Transporting of Aggregates: If aggregates are to be transported from a central proportioning plant to the mixer in batch-boxes or dump trucks, such equipment shall be of sufficient capacity to carry the full volume of materials for each batch of concrete. Partitions separating batches shall be approved by the Engineer and shall be adequate and effective to prevent spilling from one compartment to another while in transit or being deposited.

B.5 Storage of Cement: Cement may be stored in securely locked dry places either in bulk (unpacked) or in bags.

a) All cement bags shall be marked with the date of manufacture and with the date of storage so that they can be taken out for use in the same order as they were brought in to storage.

b) Cement bags shall be placed on wooden shelves at least 100 mm above ground and 150 mm clear of walls.

c) Unpacked cement shall not be used six months after manufacture and bagged cement three months after manufacture unless it has been retested in accordance with 5.01.02 A13.

d) No cement shall be used which has been affected by humidity regardless of the date of manufacture.

e) Cement shall be transported to the mixer in the original sacks. Each batch shall contain the full amount of cement for the batch. Batches where cement is placed in contact with the aggregates may be rejected unless mixed within 1.5 hours.

C. Mixing

Concrete shall be mixed in the quantities required for immediate use. Concrete shall not be used which has developed initial set. Retempering concrete by adding water or by other means shall not be permitted. Concrete that is not within the specified slump limits at the time of placement shall not be used and shall be disposed of as directed by the Engineer.

C.1 If washed sand is used while still wet the mixing time starts with the addition of cement to the aggregate, even if the water required for the mixing has not been added.

C.2 The concrete shall be mixed at the site of the Works, in a central-mix plant, or in truck mixers. The mixer shall be of a type and capacity approved by the Engineer. Ready-mixed concrete shall be mixed and delivered in accordance with the requirements of Sub-Section 5.01.7 "Ready-Mixed Concrete and Central-Mixed Concrete".

C.3 The coarse aggregate shall first be loaded into the mixer followed by the fine aggregate. Some mix water shall be added to the mix before the cement is loaded into the mixer. Water shall be continuously added throughout mixing. Additives, if required and approved by the Engineer, shall be added according to the manufacturer's instructions. Retarders shall be added within one minute or 25% of the total mixing time whichever is the smaller.

C.4 The manufacturer's instructions shall be followed in respect of overloading the mixer and the selection of the rate of revolution of the mixers.

C.5 To avoid segregation in the fresh concrete, the free drop height on emptying the mixer shall be not greater than 1.5 metres.

C.6 After mixing, the concrete shall be homogeneous and comply with the provisions of these specifications. The Engineer shall, if the mix fails to produce concrete of the required strength, vary the mix time.

D. Central Mixing

Plants for concrete shall comply with the following requirements, in addition to those set forth above:

D.1 **Cement:** The provisions for storing cement shall be approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of previous cement batches before starting to manufacture concrete for the Works.

D.2 **Aggregate:** Coarse and fine aggregate to be used in concrete shall be kept in stockpiles and bins apart from aggregate used in other work. Aggregate shall be provided from a source approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of previous aggregate batches before starting to manufacture concrete for the Works.

D.3 **Consistency:** The Contractor shall be responsible for producing concrete that is homogeneous and complies with the provisions of these specifications.

D.4 **Hauling:** Mixed concrete from the central-mixing plant shall be transported in truck mixers, truck agitators or non-agitating trucks having special bodies or other approved containers.

D.5 **Time of Haul:** The time elapsing from the time water is added to the mix until the concrete is deposited in place shall be not greater than the following:

For concrete produced on site and transported by means other than transit mixers or agitated trucks.

- Thirty minutes when the air temperature is 25°C or higher.
- Forty minutes when the air temperature is 18°C or below.
- Interpolated time when the air temperature is between 18°C and 25°C.

For concrete transported by transit mixer or agitators, the time taken for 300 revolutions of the transit mixer or agitator or 20 minutes, whichever is the lesser.

The maximum haul time may be reduced at the Engineer's discretion if the slump changes or there are signs of the concrete beginning to dry.

D.6 **Delivery:** When supplying concrete from a central plant, the Contractor shall have sufficient plant capacity and transporting equipment to ensure continuous delivery at the rate required. The rate of delivery of concrete during concreting operations shall be regulated to provide for proper handling, placing and finishing of the concrete and the method of delivery and handling the concrete shall be organised to facilitate placing with a minimum of rehandling and avoidance of damage to the structure or the concrete. Methods of delivery and handling for each site shall be approved by the Engineer. The Engineer shall delay or suspend the mixing and placing of concrete at any site, for which he considers the Contractor's delivery equipment inadequate, until such time as the Contractor provides additional approved delivery equipment.

5.01.7 READY-MIXED AND CENTRALLY- MIXED CONCRETE

A. General

A.1 Ready-Mixed Concrete and Centrally-Mixed Concrete shall consist of a mixture of cement, water and aggregate, without air entrainment or water-reducing admixture. Air-entrainment, water-reduction or other type of admixture shall only be used at the Engineer's discretion. The terms ready-mixed or central-mixed concrete shall include transit-mixed concrete and will be referred to hereinafter as ready-mixed concrete.

A.2 Ready-mixed concrete shall only be used in construction of the Works with the Engineer’s approval.

A.3 Approval of any ready mixed concrete plant will be granted only when an inspection of the plant indicates that the equipment, the method of storing and handling

the materials, the production procedures, the transportation and rate of delivery of concrete from the plant to the point of use, all meet the requirements set forth herein.

A.4 Ready-mixed concrete shall be mixed and delivered to the point of use by means of one of the following combinations of operations:

a) Mixed completely in a stationary central mixing plant and the mixed concrete transported to the point of use in a truck mixer or tank agitator operating at agitator speed, or when approved by the Engineer, in non-agitating equipment (centrally-mixed concrete).

b) Mixed completely in a truck mixer at the batching plant or while in transit (transit-mixed concrete).

c) Mixed completely in a truck mixer at the point of use following the addition of mixing water (truck-mixed concrete).

A.5 Permission to use ready-mixed concrete from any previously approved plant shall be rescinded upon failure to comply with the requirements of the Specification.

B. Materials

All materials used in the manufacture of ready-mixed concrete shall conform to the requirements of Sub-Section 5.01.2: Materials.

C. Equipment

Equipment shall be efficient, well maintained and of the type and number as outlined in the Contractor's Programme of Work. Transit mixers and agitator trucks shall comply with the standards specified in ASTM C94. Non-agitating equipment used for transporting concrete shall be watertight and equipped with gates permitting controlled discharge of concrete and fitted with covers for protection against the weather.

D. Supply

D.1 Where transit mixers are used, the constituent materials shall be mixed dry in the mixer and water added directly before the pour and mixed at the speed and number of turns in accordance with the manufacturer’s recommendations.

D.2 Where concrete is mixed at a central plant, on or off site, the concrete shall be supplied to the pouring area by agitator trucks or transit mixers which rotate at the speed specified by the manufacturers. Non-agitating trucks shall only be permitted if the central plant is on site.

D.3 The time of haul shall not exceed the maximum stated in sub-item D.5 of subsection 5.01.6 of the Specification.

E. Uniformity Tests

Four samples of fresh concrete shall be taken, two after 15% of discharge from the truck mixer or agitator truck and two after 85% discharge and within 20 minutes. Slump and compaction factor tests shall be carried out including any other tests specified or required by the Engineer.

F. Samples

F.1 Samples for strength test shall be taken as specified in Clause C of subsection 5.01.4 of the Specification.

F.2 At least six specimens shall be prepared per sample. Three of these shall be tested at 7 days and three at 28 days.

G. Control of Delivery

G.1 Drivers of delivery trucks shall be provided with trip tickets, which shall be signed by a responsible member of the central plant staff, for submission to the Engineer. The ticket shall contain the following information.

- Name and address of the Central Plant.
- Serial number of the ticket and date.
- Truck number.
- Class and/or strength of concrete.
- Cement content of the mix.
- Loading time.
- Slump
- Any other relevant information.

G.2 The Engineer shall send representatives to the central plant at any time to:

- Check the batching and mixing.
- Verify loading time.
- Take a copy of the trip ticket.

G.3 The Contractor and/or concrete supplier shall afford the Engineer and/or his representative, without charge, all facilities necessary to take samples, conduct tests and inspect the central plant to determine whether the concrete is being furnished in accordance with the Specification.

G.4 Concrete delivered in outdoor temperatures lower than 5 ^{o}C, or if the temperature is expected to drop below 5 ^{o}C during the curing period, shall arrive at the Works having a temperature of not less than 10 ^{o}C nor greater than 32 ^{o}C.

G.5 In supplying ready-mixed concrete, the plant shall have sufficient batching and transporting capacity to ensure continuous delivery at the rate required. The rate of delivery of concrete during concreting operations shall be sufficient for the proper handling, placing and finishing of concrete. If the rate of delivery is not sufficient for a continuous concrete operation, the Engineer shall suspend all or parts of further concrete work until such time as the Contractor provides adequate additional delivery equipment which, in the opinion of the Engineer, provides a continuous concrete operation.

5.01.8 MEASUREMENT

A. Scope

Concrete works to be measured for payment under Section 5.01 include mass, reinforced and prestressed concrete of both in-situ and precast construction of a general nature but do not include specific components of highway structures, such as concrete piles, concrete parapets and safety barriers, precast concrete kerbs and tiles etc., which are separately described in other sections of the Specification.

B. Measurement

B.1 Concrete shall be measured by the cubic metre in place and accepted by the Engineer, based on the dimensions shown on the Drawings or as otherwise directed by the Engineer.

B.2 Different classes of concrete shall be measured separately.

B.3 Concrete formed by different types of formwork and/or falsework shall be measured separately.

B.4 Concrete of the same class requiring the same formwork but different class of surface finish shall be measured separately.

B.5 Voids, openings or gaps whose size is 0.05 cubic metres or more shall be measured and deducted from the volume of concrete in which they occur.

B.6 All service ducts, irrespective of diameter, shall be measured and deducted from the volume of concrete in which they are located.

B.7 The following deductions in the measurement of the volume of concrete shall not be made:

- Reinforcing bars
- Prestressing ducts, anchors, cones, couplers and grouting tubes
- Embedded metals (bolts, nuts, anchorages, hooks etc)
- Rock plums

- Holes introduced by the Contractor for the convenience of transportation, erection or construction shall not be measured for deduction irrespective of the size of the holes and whether or not the holes are made good.

B.8 Additional concrete placed by the Contractor for the purpose of facilitating his work shall not be measured for payment.

C. Item Coverage

The Contract price paid per cubic metre for concrete shall include full rates for furnishing all labour, materials, tools, equipment and incidentals including, but not limited to, the following: -

- Cement, aggregates, water and additives, admixtures and air entraining agents including their testing, storage, handling and transportation.
- Washing of aggregates, if required.
- Ice, if required, added in the mix water.
- Plant, machinery and equipment required for the production of concrete.
- Design of mixes, taking samples and testing specimens.
- Transportation and delivery of concrete to work areas.
- Placing, vibrating and finishing of concrete.
- All formwork irrespective of the material used and the quality of surface finish specified.
- All falsework supporting and stabilising formwork.
- Curing of concrete.
- Tooling, if required, to achieve the specified surface finish.
- Corrective measures and the means of carrying them out required in the event of the concrete being not in accordance with the Drawings and/or specification.
- Handling, transportation and erection of precast concrete members.
- Grout and/or epoxy used in precast construction including material and equipment for temporary prestress, if required.
- Material, plant and equipment associated with particular methods of construction.
- Joint fillers, joint sealants, weep holes, water stops, dowel bars as shown on the drawings including material, plant handling, transportation testing, storage, workmanship and associated accessories.

SECTION 5.02: CONCRETE HANDLING, PLACING AND CURING

5.02.1 SCOPE

The work covered in this Section consists of the placing, compacting and curing of concrete for mass concrete, reinforced concrete and prestressed concrete structures.

5.02.2 MATERIALS

All concrete materials shall comply with Specification section 5.01: Concrete Mixes and Testing.

5.02.3 PLACING

A. General

A.1 Before preparing and placing any concrete, the Contractor shall submit a work plan to the Engineer for approval, specifying the characteristics of the concrete to be employed, the time at which placing is to start the methodology and the duration. The Engineer's approval at least 24 hours in advance of each placing is required.

A.2 The method and sequence of pour, the equipment to be used, the method of compaction and curing procedures shall be approved by the Engineer, prior to any concrete pour.

A.3 In order to allow satisfactory vibration, the concrete shall be placed in horizontal layers, no thicker than fifty centimetres.

A.4 If the concrete is placed in successive phases, there shall be no separation, discontinuity or difference in appearance between the two successive placings. Before each successive placing, the surface of the in-place concrete shall be carefully roughened, cleaned, washed free of loose particles and dampened.

A.5 Concrete shall be placed so that it shall be undisturbed once trowelled. Slabs shall be poured by starting placement of concrete at the location furthest away from the access point to minimise disturbance by workers or equipment.

A.6 Concrete placed in upright reinforced concrete structures shall either be completed or interrupted for a period of twenty-four hours to avoid the risk of the placed concrete debonding from the reinforcing bars during setting and the initial phase of hardening.

A.7 The temperature of the concrete being placed shall be of the same magnitude as that of the reinforcing bars to avoid poor adhesion. The reinforcing bars shall be protected from the sun or cooled by water jets prior to the placing of the concrete or the pouring shall start during the cooler hours of the day and be suspended when the temperature rises above 33 ^{o}C, unless otherwise agreed with the Engineer.

A.8 The free-drop height of concrete shall be not greater than 1.5m and the method of placing shall suit the conditions and prevent segregation.

A.9 Placing of concrete shall be continuous between predetermined points such as construction joints, contraction joints and expansion joints.

A.10 Concrete shall be placed to avoid segregation of the materials and displacement of the reinforcement. Concrete shall not be deposited in large quantities at any point and then run or worked along the forms, causing potential segregation of materials.

A.11 The concrete shall be deposited between the forms in horizontal layers and the work shall be carried out continuously between predetermined planes agreed upon by the Contractor and the Engineer.

A.12 The slopes of chutes, where used, shall be not greater than 1 vertical to 2 horizontal or smaller than 1 vertical to 3 horizontal. The slope of the chute shall be constant along its length. The capacity of the chute shall be adequate to deliver the required volume of concrete at the required rate.

A.13 Aluminium pipes shall not be used for delivering concrete. The internal diameter of delivery pipes, if used, shall be not less than 8 times the maximum aggregate size. At the point of delivery, pipes shall be vertical.

A.14 Where buckets and hoppers are used for delivery of concrete, the discharge opening shall be not less than 5 times the maximum aggregate size. The sides of hoppers shall be sloped at not less than 60 degrees to the horizontal.

A.15 When buggies are used to transport fresh concrete, they shall be run on level tracks, which are securely fixed. The buggies shall be run smoothly without sudden jerks and the distance travelled shall be not greater than 60 metres.

A.16 All chutes, buckets, hoppers, buggies and pipes shall be kept clean and free from coatings of hardened concrete by thorough flushing with water after each pour. The water used for flushing shall be discharged clear of the concrete already in place.

A.17 The external surface of all concrete shall be thoroughly worked during the placing using appropriate tools. The method of working shall force all coarse aggregate from the surface and bring mortar against the forms to produce a smooth finish, substantially free from water and air pockets and honeycombing.

A.18 Concrete shall be deposited in water only with the permission of the Engineer and under his supervision. The minimum cement content of the class of concrete being deposited in water shall be increased 10 per cent without further compensation and the slump shall be approximately 15 centimetres.

A.19 When depositing in water, the concrete shall be carefully placed in the space in which it is to remain in a compact mass, using a tremie, bottom-dumping bucket or other method approved by the Engineer that does not permit the concrete to fall through the water without adequate protection. The concrete shall not be disturbed after being deposited. No concrete shall be placed in running water. Forms that are not reasonably watertight shall not be used for holding concrete deposited under water.

A.20 When casing is used in drilled shafts, the casing shall be smooth and properly oiled in accordance with the manufacturer's recommendations and shall extend sufficiently above the grade of the finish shaft to provide excess concrete to compensate for the anticipated slump due to the casing removal. The concrete placed in the casing shall have such a slump and be of such workability that vibration of the concrete is not required.

A.21 No concrete work shall be stopped or discontinued within 45 centimetres of the top of any finished surface unless such work is to be finished with a coping having a thickness of less than 45 centimetres. In this case the joint shall be made at the underside of the coping.

A.22 Concrete in slab spans shall be placed in one continuous operation for each span, unless otherwise shown on the Drawings or directed by the Engineer.

A.23 Concrete in in-situ beam and slab construction shall be placed in one continuous operation, unless otherwise shown on the Drawings or approved by the Engineer. If concrete is to be placed in two separate operations, each placement shall be continuous; first, to the top of the girder stems, and second, to completion. Where a construction joint is permitted between the girder stem and the roadway slab, shop drawings including complete details of key or other methods of bonding shall be prepared by the Contractor and submitted to the Engineer for approval. When such a joint is permitted, deck concrete shall not be placed until the concrete in the girder stem has hardened sufficiently so as not to be damaged by the concreting operations of the deck pour.

A.24 Concrete in arch rings shall be placed so that the cantering is loaded uniformly. Arch rings shall be divided into sections such that each section can be cast for the full cross-section in one continuous operation. The arrangement of the section and the sequence of placing shall be as approved by the Engineer and shall avoid the creation of initial stress in the reinforcement. The section shall be bonded together by suitable keys or dowels. When permitted by the Engineer, arch rings shall be cast in a single continuous operation.

A.25 The method used for transporting concrete batches, materials or equipment over previously placed floor slabs or floor units or over units of structures of continuous design types shall be subject to approval by the Engineer. Trucks, heavy equipment and heavy concentrations of materials are prohibited on floor slabs until the concrete has attained its design strength.

B. Pumping

B.1 The use of pumps shall be permitted only after they have been checked and approved by the Engineer. Only low pressure piston type pumps, working with a water/cement ratio of not more than sixty five hundredths (0.65), shall be permitted. The use of superplastizisers to facilitate pumping for low water/cement ratios shall be permitted, subject to Engineer's review and approval.

B.2 The use of high pressure pumps for pumping concrete is not permitted.

B.3 The mix design shall be checked and approved by the Engineer for suitability for pumping and the concrete shall be tested regularly during pumping for its uniformity and fitness for purpose. If changes to slump, water-cement ratio, consistency or any other characteristics occur, corrective measures shall immediately be taken to ensure that concrete delivered by the pump complies with the requirements of the Specification. Samples shall be taken at the discharge from the mixer/agitator trucks, from the pumps and at the discharge from the pumps.

B.4 The internal diameter of pump delivery pipes shall be not less than three times the maximum aggregate size. The pipes shall not rest on any part of the formwork and shall be supported independently and securely and be readily accessible so that sections can easily be detached to remove any blockage.

B.5 Before approving the use of a pump, the Engineer shall verify that the Contractor has sufficiently resources in the concrete placing team and the necessary equipment for placing and vibrating the concrete.

B.6 The placing of pumps within the forms while concrete is being placed shall not be permitted. When flood prevention is necessary, a seal of concrete shall be placed through a closed chute or tremie and allowed to set to form a barrier.

5.02.4 COMPACTION

A. General

A.1 The vibration of the concrete shall be considered completed when a thin layer of cement grout appears on the surface and when no more air bubbles, indicating the presence of voids within the concrete, appear on the surface. Vibration shall be limited to prevent segregation.

A.2 Vibration shall be carried out by one of the following methods:

- Internal
- External
- Mixed.

A.3 Vibration shall be carried out in accordance with the guidelines as given in Standard Practice for Consolidation of Concrete (ACI 309) of Part 2 Concrete Practices and Inspection, Pavements, of ACI Manual of Concrete Practice 1988 issued by American Concrete Institute (ACI), unless otherwise directed by the Engineer.

A.4 Internal Vibration shall be executed in all sections which are sufficiently large to permit the insertion and manipulation of immersion vibrators, previously approved by the Engineer and in accordance with the following recommended practices:

- The concrete shall be placed in horizontal layers no thicker than fifty centimetres.
- The vibrator shall be inserted vertically into the concrete to its full length to reach the bottom of the freshly placed layer.
- The distance between two successive insertions shall not exceed five times the diameter of the vibrator itself.
- The vibrator shall not rest on or against either the formwork or the main reinforcing bars.

A.5 External Form Vibrators shall be used for external vibration when it is impossible to use internal vibrators (heavily reinforced thin walls, pipes or other precast, small cross-section element, etc). The water/cement ratio shall be low (0.30 -0.40) in order to avoid segregation of the concrete, to provide rapid hardening and for the early removal of formwork.

A.6 Mixed Vibration shall be used in the construction of reinforced or prestressed concrete beams. External wall vibrators shall also be used, mounted on the outside of the formwork after this has been suitably reinforced with ribs of U-bars. The mounting of the wall vibrators shall be welded to this reinforcement. Mountings shall be symmetrically positioned on each side of the beam to produce a rotary movement within the concrete during vibration from the bottom towards the top and from the part placed first towards the part placed last.

A.7 Only vibrators in the zone of the formwork with newly placed concrete shall be used. As the casting of the beam advances, the vibrators shall be dismounted and remounted as necessary.

A.8 Elastic supports shall be provided both under the bottom of the beam and in alignment with the braces or tie rods of the formwork walls.

A.9 The network of reinforcing bars and tensioning cables shall not move as a result of the vibration. Special ties (passing through the formwork walls) or spacers shall be used.

A.10 The Contractor shall submit to the Engineer a method statement for approval of his vibration proposals prior to carrying out the work, giving the following details:

- The position of the external wall vibrators.
- The power, frequency and amplitude of the external wall vibrators.
- The number of wall vibrators that will be utilized at the same time.
- The number and type (frequency and size) of the internal vibrators to be used for the consolidation of the concrete.
- The position of the spacers, or the number of ties, to be used to ensure that the reinforcing bar network and the tensioning cables (if any) do not move during vibration.
- The method of placement of concrete and the length of time this operation is expected to take.

A.11 When required, vibration shall be supplemented by hand spading with suitable tools to assure proper and adequate compaction.

B. Poker Vibrators

B.1 The type and size of poker vibrators shall suit the pour size, density of reinforcement and member dimensions. Unless otherwise authorized by the Engineer, the vibrators shall be selected from Table 5.2.1 below:

TABLE 5.2.1: SELECTION OF POKER DIAMETER FOR SIZE OF POUR

Size of Pour (m^3/h)	Poker Diameter (mm)	Speed (Vibrations/min)
2 - 4	20 - 45	9000
5 - 10	50 - 65	9000
10 - 20	60 - 75	7000
20 - 30	80 - 115	7000
30 - 40	140 - 170	6000

B.2 Poker vibrators shall be inserted into the concrete vertically at regular intervals which shall be no greater than 0.5m. They shall be inserted quickly and withdrawn slowly. The withdrawal rate shall be not more than 75mm/sec. the cycle of insertion and withdrawal shall be between 10 and 30 seconds.

B.3 Poker vibrators shall be kept clear of formwork and concrete previously cast.

B.4 Vibrators shall be manipulated to work the concrete thoroughly around the reinforcement and embedded fixtures and into the corners and angles of forms. Vibrators shall not be used to make concrete flow or run into position in lieu of placing.

B.5 Compaction shall be sufficient to achieve the maximum density without segregation in the fresh concrete.

B.6 Standby pokers of the same type shall be provided at all times. The number of spares shall be not less than half the number of pokers used for compaction of the pour.

B.7 Vibration shall only be carried out by operatives having previous experience in this type of work.

C. Other Vibrators

C.1 Form vibrators, vibrating tables and surface vibrators where required shall first be approved by the Engineer and shall conform to the requirements of ACI-309.

C.2 Where form vibrators are used, the form shall be adequately designed so that the vibration does not cause joints to leak or dimensions and geometry to alter.

C.3 Unless otherwise permitted by the Engineer, the use of form vibrators shall be limited to members whose thickness does not exceed 150 mm.

5.02.5 CURING

A. Materials

A.1 **Hessian or Burlap** shall be clean and free from harmful materials. The unit weight of either hessian or burlap shall be not less than 230g/ m^2.

A.2 **Impermeable membranes:** The following impermeable membranes may, with the Engineer's approval, be used.

- Clear polyethylene film with no holes, tears, scratches or contamination of any type.
- Hessian coated with white polyethylene of density not less than 300g/sq.m. The coating may be on one side only but shall be not less than 0.1mm thick and shall not peel during and after use.

A.3 **Curing Compounds** shall conform to AASHTO M148 (ASTM-C309).

A.4 **Sand** shall be natural sand, free of silt, clay and other contaminants harmful to the concrete.

A.5 **Water** shall satisfy the requirements of Section 5.01 of the Specification.

B. Method of Curing

B.1 General: The method of curing shall be approved by the Engineer. It shall not cause any undesirable blemishes such as surface discoloration and surface roughness. Curing compounds shall not be used on construction joints and surfaces that are to receive waterproofing, paint or membranes.

B.2 Ponding: Curing by ponding may be used for horizontal surfaces such as bases, pile caps and slabs. Large horizontal surface areas shall be separated into ponds not exceeding 5 m^2. The ponds shall first be filled between 12 to 24 hours after the pour, unless otherwise authorised by the Engineer, and shall be replenished from time to time so as to maintain the ponding for the specified curing period. The temperature of the curing water shall be not greater than 10°C.

B.3 Sprinkling: Unless otherwise approved by Engineer, curing by spraying shall commence between 12 and 24 hours after the concrete pour. The concrete shall be maintained in a damp condition at all times during the curing period by periodic light spraying.

B.4 Wet Hessian/Burlap: Members to be cured by wet hessian or wet burlap shall be completely wrapped with the material which shall be kept moist at all times by regular spraying during the curing period. Unless otherwise approved by the Engineer, the overlap under normal conditions shall be not less than one-quarter the width of the hessian or burlap and not less than one-half the width in windy and/or rainy conditions. Before members are wrapped for curing, they shall first be evenly moistened. Unless approved by the Engineer, burlap shall be supplied only in rolls; burlap bags shall not be used. Second-hand hessian and burlap, if approved for use, shall be clean without holes and contamination of any kind.

B.5 Waterproof Sheets: Waterproof sheets used for curing shall, unless directed by the Engineer, be spread immediately after the pour. The sheet shall be clear of the concrete surface but be arranged to prevent air movement over the concrete surface. Waterproof sheets shall not be used when the air temperature is 25°C or higher.

B.6 Curing Compounds: Curing compounds shall be applied in two applications at a rate of not less than 1 litre/ 7.5 m^2 per application or as recommended by the manufacturer.

- The first coat shall be applied immediately after the removal of the forms and acceptance of the concrete finish and after the disappearance of free water on unformed surfaces. If the concrete is dry or becomes dry, it shall be thoroughly wet with water and curing compound applied just as the surface film of water disappears. The second application shall be applied after the first application has set. During curing operations, any unsprayed surfaces shall be kept wet with water. The curing membrane shall not be allowed on areas against which further concrete is to be placed.

- Hand operated spray equipment shall be capable of supplying a constant and uniform pressure to provide a uniform and adequate distribution of the curing membrane at the rates required. The curing compound shall be thoroughly mixed at all times during usage.
- The curing membrane shall be protected against damage for the entire specified curing period. Any coating that has been damaged or otherwise disturbed shall be given an additional coating. Should the curing membrane be continuously subjected to damage, the Engineer shall instruct wet burlap, polyethylene sheeting or other material to be applied at once.
- No traffic of any kind shall be permitted on the curing membrane until the curing period is completed, unless agreed to by the Engineer. Areas damaged by traffic shall be immediately repaired as directed by the Engineer.

B.7 Steam Curing

Low pressure steam curing shall be carried out in accordance with ACI 517 recommendations and high pressure steam curing in accordance with ACI 516.

C. Curing Time

C.1 The minimum curing time shall be the number of days given in Table 5.2.2 below. If the surface temperature of the concrete falls below 10°C the curing time shall be calculated from the equivalent maturity criteria.

TABLE 5.2.2: NORMAL CURING PERIODS

Ambient Weather Conditions	**Minimum Number of Days of Curing Protection where the Surface Temperature of the Concrete Exceeds 10°C for the Whole Curing Period**			***Equivalent Maturity in Degree Celsius Hours – (The required number of hours of curing of the Concrete multiplied by the Number of °C by which the initial surface temperature of the Concrete exceeds minus 10°C)***		
	OPC or RHPC	**SRPC**	**Other**	**OPC or RHPC**	**SRPC**	**Other**
Hot Weather* or Drying Winds	**4**	**3**	**7**	**2000**	**1500**	**3500**
Other Conditions	**3**	**2**	**4**	**1500**	**1000**	**2000**

KEY. OPC = Ordinary Portland cement.
RHPC = Rapid-hardening Portland cement.
SRPC = Sulphate resisting Portland cement.
* See Clause 5.02.6A

C.2 The minimum curing time given in Table 5.2.2 above shall be compared with the time required for cylinders (or cubes), cured under identical conditions to those which the concrete is subjected, to attain 70% of the characteristic strength. The greater shall be taken as the minimum curing time.

5.02.6 HOT WEATHER CONCRETING

A. Definitions

For the purpose of this sub-section of this Specification, Hot Weather is as defined in ACI 305R-77 (Revised 1982) Chapter 1.

B. General

B.1 The production, delivery, placing, curing, testing and inspection of concrete shall be in accordance with these Specifications and the recommendations of ACI 305R-77 (Revised 1982).

B.2 No concreting shall commence when the air temperature is 32°C and rising. The Contractor shall schedule his operations to place and finish concreting during the hours that the air temperature will be below 32°C. This should preferably be in the latter part of the day after the maximum temperature has been reached.

C. Control of Temperature

C.1 Aggregate stockpile shall be protected from direct sunlight by suitable covering and periodically sprayed with clean water.

C.2 Water shall be stored in tanks away from sunlight and insulated by suitable means to protect against high air temperatures. Water tanks liable to be exposed to sunlight shall be covered with suitable reflective paint such as white gloss.

C.3 Sufficient ice shall be added to the mix water to ensure that the temperature of the fresh concrete shall not exceed 32°C.

C.4 The temperature of the concrete at the time of placing shall not be permitted to exceed 33 °C. Concrete materials shall be stored in a cool shaded position away from the direct rays of the sun. Prior to mixing, aggregates shall be cooled and water shall be cooled by means of a proprietary water chilling plant as necessary. The prices in the Bill of Quantities shall be deemed to cover all such special work.

C.5 Additives as recommended in ACI 305R-77 shall be used to improve workability and/or delay initial setting.

C.6 Retarding admixtures to facilitate placing and finishing of the concrete shall conform to AASHTO M194, Type D and only be used if approved by the Engineer.

D. Mixing and Placing

D.1 The Contractor shall take appropriate precautionary measures when handling and placing of concrete during periods of high temperatures. Concrete shall be covered with damp hessian during transportation. No additional water shall be added at the time of mixing without the approval of the Engineer, to minimise the risk of additional shrinkage of the concrete. Water shall not be added during transportation or placing of the concrete.

D.2 Aggregates and cement shall be thoroughly pre-mixed before adding water.

D.3 Transit mixers, if used, shall be coated with a reflective paint and shall be kept out of direct sunlight while waiting to be discharged.

E. Concrete Protection

E.1 Before the concrete shutters are struck, the formwork and shuttering shall be cooled with a water spray.

E.2 The concrete and the falsework shall be protected against sunlight.

E.3 Hessian, if used for curing, shall be coated with a white polyethylene backing.

E.4 Concrete exposed to strong winds shall be protected with windbreaks. The windbreaks shall be kept moist by regular spraying.

5.02.7 COLD WEATHER CONCRETING

A. Definitions

For the purpose of this sub-section of this Specification, Cold Weather is as defined in ACI 306.1-87, Section 1, Part 1.2.

B. General

B.1 ACI 306.1-90 "Standard Specification for Cold Weather Concreting" applies.

B.2 The production and delivery of concrete, the placing and curing and the protection requirement shall be in accordance with the recommendations of ACI 306R-88 "Cold Weather Concreting".

B.3 No concreting shall commence when the air temperature is 6°C and falling, unless authorised by the Engineer.

C. Mixing and Placing

C.1 Aggregates, water, forms, reinforcement etc. shall be free of snow, frost or ice.

C.2 If aggregates and water are pre-heated, they shall be mixed together prior to introducing cement. The aggregates shall not be pre-heated to a temperature in excess of 100°C, the water shall not be in excess of 60°C and the temperature of the water and aggregate mix, before the introduction of cement, shall not exceed 38°C.

C.3 If heated water is added to unheated aggregates, the temperature of the water and aggregate mix, before the introduction of cement, shall not exceed 38°C.

C.4 The temperature of concrete at the time of discharge shall be between 10°C and 27°C and for three days after the pour not less than 5°C.

D. Protection

D.1 Concrete shall be protected against cold winds by suitable windbreaks.

D.2 Adequate insulation using boards, planks, sheets etc. shall be provided to maintain the required minimum concrete temperature during the curing period.

D.3 Protection measures shall be maintained until the concrete attains a strength of at least 65% of the characteristic strength.

5.02.8 NIGHT CONCRETING

A. Night concreting shall not be carried without prior approval from the Engineer.

B. Details of the lighting system shall be submitted in advance of the proposed concreting for the Engineer's approval. At least one stand-by generator shall be provided at all times during concreting operation.

5.02.9 MEASUREMENT

The provisions of this section of the Specification are not measured directly for payment but shall be considered subsidiary to the different classes of concrete described and measured for payment under the provisions of Specification Section 5.01: Concrete Mixes and Testing

SECTION 5.03: STEEL REINFORCEMENT

5.03.1 SCOPE

The work covered in this Section consists of the supply and fixing of the unstressed steel bars, wires, mesh and mats for the reinforcement of concrete in accordance with the Drawings and Specification.

5.03.2 MATERIALS

A. Reinforcing Bars

A.1 High tensile steel reinforcement bars shall conform to AASHTO M31 (ASTM A615) Grade 60 (with carbon content not exceeding 0.3%) or to BS 4449:2005.

A.2 Mild steel reinforcing bars shall conform to AASHTO M31 (ASTM A615) Grade 40 or BS 4449:2005.

A.3 High tensile, low-alloy steel deformed bar shall conform to ASTM A706.

B. Welded Fabric Reinforcement

B.1 Welded steel wire fabric shall conform to AASHTO M55 (ASTM A185) or BS 4482:2005.

B.2 Cold drawn steel wire shall conform to the requirements of AASHTO M32 or in the case of hard drawn steel wire to BS 4482:2005.

C. Fabricated Mat Reinforcement

Fabricated mat reinforcement shall conform to AASHTO M54 (ASTM A184).

D. Certification and Identification

D.1 Three copies of a Mill Test Report shall be supplied to the Engineer for each lot of billet steel reinforcement supplied for use on the Contract. The Mill Test Report shall give the following information:

- The processes used in the manufacture of the steel from which the bars were rolled.
- Identification of the furnaces and/or each lot of steel from which the bars were rolled.

D.2 The bars in each lot shall be legibly tagged by the manufacturer and/or fabricator. The tag shall show the manufacturer's test and lot number or other designation that will identify the material with the certificate issued for the lot of steel.

D.3 The fabricator shall furnish 3 copies of a certificate which shows the heat number or numbers from which each size of bar in the shipment was fabricated.

E. Inspection and Sampling

The sampling and testing of reinforcement bars shall be made at the source of supply when the quantity to be shipped or other conditions warrant such procedure. Bars not inspected and sampled before shipment shall be inspected and sampled after arrival at the site.

5.03.3 CONSTRUCTION

A. General

A.1 Reinforcing steel shall be protected at all times from damage. All reinforcement shall be free from dirt, mill scale, scaly rust, paint, grease, oil or other foreign substances. There shall be no evidence of pitting or visual flaws in the test specimens or on the sheared ends of the bars.

A.2 Rust shall be removed by wire brushing or by sand blasting. Light rust without visible sign of peeling need not be removed.

B. Storage

B.1 Reinforcement shall be stored clear of the ground on platforms, skids or other supports and be protected against contamination by dirt, grease, oil etc. If directed by the Engineer, the Contractor shall provide cover to the reinforcement.

B.2 Reinforcement of different grades and different diameters shall be stored separately and appropriately marked to facilitate inspection and checking.

C. Cutting and Bending

C.1 Cutting and bending of reinforcement shall be based on bar bending schedules detailed on the Drawings and/or approved by the Engineer.

C.2 Reinforcement shall be cut using specialist cutting machines or cold cut by hand only. Cutting with oxyacetylene torches is not permitted.

C.3 Bars shall be bent to the following bend diameters:

Bar Diameter (d)	Mild Steel	High Yield Steel
Up to 16 mm	4d	4d
16 to 25 mm	4d	6d
25 to 35 mm	6d	8d
35 to 60 mm	10d	10d

C.4 All reinforcement shall be bent within the temperature range of 5°C and 100°C. Bending by heating shall not impair the physical and mechanical characteristics of the bar.

C.5 The straight bar length for a hook of 180° shall be not less than 4 times the bar diameter or 60mm whichever is the larger.

C.6 The straight bar length of a hook of 90° shall be not less than 12 times the bar diameter.

C.7 The straight bar length after a hook in stirrups shall be 6 times the bar diameter or 60mm whichever is the larger.

C.8 Cold worked bars and hot rolled high yield bars shall not be re-bent or straightened once having been bent, unless otherwise shown on the Drawings. Where it is necessary to bend mild steel bars projecting from the concrete, the bend diameter shall comply with the requirements of item C.3 above.

C.9 If bending of a bar causes the bar to crack, the bar shall be rejected, irrespective of any prior approval that may have been given, and removed from the Site.

C.10 Bars shall be cut and bent to the following tolerances:

Bar Length (mm)	**Tolerance (mm)**
Up to 1000	5
1000 - 2000	+5, -10
Above 2000	+5, -25

C.11 No adjustment to bar length after bending shall be permitted.

D. Fixing

D.1 Reinforcement shall be placed and maintained in the position shown on the Drawings. Unless agreed otherwise by the Engineer, all bar intersections shall be securely tied together with the ends of the wire turned into the main body of the concrete. 1.2 mm diameter stainless steel wire shall be used for in-situ members having exposed soffits; 1.6 mm diameter soft annealed iron wire shall be used elsewhere.

D.2 The correct cover to reinforcement on all exposed faces of concrete shall be maintained by using proprietary spacers. Where instructed by the Engineer the adequacy of such spacers shall be demonstrated by site trials.

D.3 Concrete cover blocks shall be of suitable dimensions and designed so that they shall not overturn when the concrete is placed. They shall be made with 10 mm maximum size aggregate and the mix proportion shall be such as to produce at least the same strength as the adjacent concrete. Tying wire shall be cast in the blocks for subsequent attachment to the reinforcement.

D.4 Wherever it is necessary for the Contractor to splice reinforcement at positions other than those shown on the Drawings, the approval of the Engineer shall be obtained. Splices shall be staggered where possible and shall be designed to develop the strength of the bar without exceeding the allowable unit bond stress.

D.5 Proprietary mechanical splicing devices shall be used only with the prior approval of the Engineer. They shall be able to withstand without slippage a force of not less than 1.25 times the characteristic yield stress of the smaller spliced bar multiplied by the cross-sectional area of the smaller bar.

D.6 Mesh reinforcement shall comply with the sizes of sheets and diameter and spacing of bars as shown on the Drawings. The sheets of mesh shall be lapped as shown on the Drawings. The method of placing and securing the mesh in position shall be approved by the Engineer.

D.7 Welding of reinforcement bars, if permitted, shall be carried out in accordance with the latest publications of the American Welding Society publication "Structural Welding Code for Reinforcing Steel", and shall be able to withstand a force of not less than 1.25 times the characteristic yield stress of the smaller of the welded bars multiplied by the cross-sectional area of the smaller bar.

D.8 Cold worked steel bars shall not be welded.

D.9 Galvanizing or epoxy coating shall be applied to the reinforcement in accordance with the Drawings or where otherwise required with the approval of the Engineer.

D.10 Dowel bars shall be coated over half of each bar with a proprietary debonding compound or fitted with plastic sleeving to the approval of the Engineer. Bars shall be fixed securely at the required level at right angles to and centred on the joint. Compressible caps shall be fitted to debonded ends of bars where necessary in the opinion of the Engineer.

5.03.4 MEASUREMENT

A. Measurement of different grades of steel reinforcement shall be based on the theoretical quantity of metric tonnes complete in place as shown on the Drawings or placed as ordered by the Engineer. No allowance will be made for clips, wire or other fastening devices for holding the reinforcement in place. Measurement shall not be made of reinforcement chairs to separate slab steel or similar reinforcement to retain wall steel or

similar usage elsewhere. Measurement of splices in reinforcement not shown on the Drawings will not be made, unless such splices were agreed or authorised by the Engineer.

B. Calculated weights for high tensile and mild steel shall be based upon Table 5.3.1.

TABLE 5.3.1: WEIGHTS OF REINFORCING BARS

Diameter mm	Weight kg/m	Diameter mm	Weight kg/m	Diameter mm	Weight kg/m
5	0.154	18	2.000	32	6.310
6	0.222	20	2.470	34	7.130
7	0.302	22	2.980	36	7.990
8	0.395	24	3.550	38	8.900
10	0.617	25	3.850	40	9.870
12	0.888	26	4.170	45	12.500
14	1.210	28	4.830	50	15.400
16	1.580	30	5.550		

C. Separate measurement shall not be made for bars of different diameters but of the same grade.

D. Fabric mesh reinforcement shall be measured separately and based on the theoretical quantity of metric tonnes complete in place as shown on the Drawings or placed as ordered by the Engineer. No separate measurement shall be made for different mesh sizes or different wire diameters.

SECTION 5.04: FORMWORK AND FALSEWORK

5.04.1 SCOPE

The work covered in this section consists of the design, supply and use of formwork and falsework for the construction of concrete highway structures.

5.04.2 DEFINITIONS

A. Formwork

The section of the temporary works used to give the required shape and support to poured concrete. It consists primarily of sheeting material, such as wood, plywood, metal or plastic sheet in direct contact with the concrete; and joists or stringers directly supporting the sheeting.

B. Falsework

Any temporary structure used to support a permanent structure while it is not self-supporting.

C. Scaffold

A temporary structure that provides access to and/or a working platform for labour, materials, plant and/or equipment.

D. Tower

A composite structure, usually tall, used principally to carry vertical loading.

E. Camber

The intentional curvature of the formwork, formed initially to compensate for subsequent deflection under load.

5.04.3 MATERIALS

A. Wood

A.1 Soft wood shall be free of faults such as splitting, warping, bending, knots etc.

A.2 The minimum grade of softwood used for falsework shall be SC3, determined in accordance with B.S 4978:1996.

A.3 Hardwood used as load-bearing wedges and packing shall be limited to those listed in Table 5.4.1.

TABLE 5.4.1: PERMITTED HARDWOODS FOR LOAD-BEARING WEDGES AND PACKING

Standard Name	Botanical Species
Ash	Fraxinus excelsior
Beech	Fagus sylvatica
Greenheart	Ocotea rodiaei
Jarrah	Eucalyptus marginata
Karri	Eucalyptus diversicolor
Keruing	Dipterocarpus spp
Oak	Quercus spp

B. Plywood

When plastic coated plywood is used, the phenol resin on melamine shall be not less than 20% of the total coating weight.

C. Steel

Steel forms shall conform to the requirements of Section 5.16 Structural Steelwork and Metal Components.

D. Aluminium

Aluminium forms shall conform to the requirements of ASTM B221.

E. Other Materials

Other material such as fibre-glass reinforced plastic, polystyrene, polyethylene, PVC, rubber, concrete, and brick shall be permitted for use in formwork if indicated on the Drawings or approved by the Engineer.

5.04.4 DESIGN

A. General

A.1 Formwork and falsework shall be designed by the Contractor and submitted to the Engineer with full design calculations, detailed drawings, material specifications and test certificates for approval. Falsework shall be capable of temperature changes without causing damage to the concrete.

A.2 Falsework design shall be in accordance with B.S 5972 "Code of Practice for Falsework".

A.3 If the Contractor intends to use ready made proprietary type of falsework, he shall submit all relevant data, including independent test certificates, which will enable the Engineer to determine whether or not the Contractor's proposed falsework is acceptable.

A.4 Notwithstanding any approval of falsework design by the Engineer, the Contractor shall not be relieved of his responsibility for the adequacy and correctness of the design, manufacture and assembly of the falsework.

B. Forms and Formwork

B.1 Formwork shall be sufficiently rigid so as to prevent any grout loss during concreting and shall not distort due to environmental effects and concreting operations in order that member dimensions, shape, required finish and texture are within the tolerances specified.

B.2 Forms and formwork shall be designed to be readily assembled, stripped and transported without distortion to panels and members of the formwork.

B.3 The method of stripping forms without damaging the concrete or textured surface finish shall be fully considered in the design.

B.4 If form liners are to be used to achieve the specified surface finish, samples of a size as directed by the Engineer shall be submitted for approval.

B.5 Form lining shall not bulge, warp or blister, nor shall it stain the concrete. Form lining shall be used in the largest practicable panels to minimize joints. Small panels of the lining material shall not be permitted. The joints in the lining shall be tight and smoothly cut. Adjacent panels of form lining shall be so placed that the grain of the wood will be in the same direction (all horizontal or all vertical). Thin metal form lining is not permitted. Undressed lumber of uniform thickness may be used as backing for form lining. Wooden ply form, of adequate thickness which is properly supported to meet the above requirements, may be used in lieu of the lined forms specified herein.

B.6 Metal forms, if used, shall be of such thickness that the forms will remain true to shape. All bolt and rivet heads shall be countersunk. Clamps, pins or other connecting devices shall be designed to hold the forms rigidly together and to allow removal without injury to the concrete. Metal forms which do not present a smooth surface or do not line up properly shall not be used. Care shall be exercised to keep metal forms free from rust, grease or other foreign matter. Under such circumstances the continued use of the metal forms will depend upon satisfactory performance and their discontinuance may be required at any time by the Engineer. Steel panels or panels with metal frames and wood or combination shall be designed to leave no lipping or ridges in the finished concrete.

B.7 The width and thickness of the lumber, the size and spacing of studs and wales shall be determined with due regard to the nature of the Work and shall be sufficient to ensure rigidity of the forms and to prevent distortion due to the pressure of the concrete.

B.8 Form bolts, rods or ties and removable ties through plastic (PVC) pipes shall be made of steel. They shall be the type which permit the major part of the tie to remain permanently in the structure or removed entirely. They shall be held in place by devices attached to the wales capable of developing the strength of the ties. The Engineer may permit the use of wire ties on irregular sections and incidental construction if the concrete pressures are nominal and the form alignment is maintained by other means. Form ties shall not be permitted through forms for handrails. Pipe spreaders shall not be used unless they can be removed as the concrete is placed. Wood or metal spreaders shall be removed as the concrete is placed. The use of cofferdam braces or struts shall not be permitted except in unusual situations and with the approval of the Engineer.

B.9 Where the bottom of the forms is inaccessible, the lower form boards shall be left loose or other provisions made so that extraneous material may be removed from the forms immediately before placing the concrete.

B.10 Unless otherwise directed by the Engineer, the exterior side of forms shall be painted with an approved, good quality high gloss white oil base enamel paint prior to placing concrete. Paint shall be applied to metal forms only. When complete coverage is not obtained with one coat, the Engineer shall order additional coats as he deems necessary to obtain complete coverage. Forms shall be repainted when ordered by the Engineer.

B.11 Unless provided otherwise on the Drawings or directed by the Engineer, all exposed edges shall be bevelled by using dressed, mill cut, triangular moulding, having 20 millimetre sides.

B.12 Forms shall be maintained after erection to eliminate warping and shrinkage.

C. Falsework

C.1 Falsework and centring shall be designed to provide the necessary rigidity to support all loads placed upon it without settlement or deformation in excess of the permissible tolerance for the structure given in the Specifications. Falsework columns shall be supported on hardwood, concrete pads or metal bases to support all falsework that cannot be founded on rock, shale or thick deposits of other compact material in their natural beds. Falsework shall not be supported on any part of the structure, except the footings, without the written permission of the Engineer. The number and spacing of falsework columns, the adequacy of sills, caps and stringers and the amount of bracing in the falsework framing shall be subject to the approval of the Engineer.

C.2 All timber shall be of sound wood, in good condition and free from defects that might impair its strength. If the vertical members are of insufficient length to cap at the desired elevation for the horizontal members, they shall preferably be capped and frames constructed to the proper elevation. Ends of the vertical members shall be cut square for full bearing to preclude the use of wedges. If vertical splices are necessary, the abutting members shall be of the same approximate size, the ends shall be cut square for full bearing, and the splices shall be scabbed using a method approved by the Engineer.

C.3 The Contractor shall compute falsework settlement and deflection for bridges so that when the final settlement is complete, the structure will conform to the required camber, section and grade as shown on the Drawings.

C.4 The Contractor shall provide means for accurately measuring settlement in falsework during placement of concrete and shall provide a competent observer to observe and correct the settlement.

C.5 Screw jacks, if used, shall be designed for use with a slenderness ratio not exceeding 60. The slenderness ratio shall be taken as the ratio of the clear distance between effective bracing in both horizontal directions to the diameter of the screw jack measured at the root of the thread. The manufacturers' certificate showing the ultimate load capacity of the screw jack shall be submitted with the design calculations for the falsework. If directed by the Engineer, the Contractor shall furnish a test certificate carried out at an approved independent laboratory.

C.6 Props and towers supporting forms or partially completed structures shall be interconnected in plan orthogonally at levels to be determined in the design. They shall also be interconnected by diagonal bracings in orthogonal vertical planes.

5.04.5 FINISHES

A. Formed Finishes

A.1 **Class F1.** This class of surface finish denotes a special finish required from aesthetic considerations as shown on the Drawings. In addition to the requirements of Class F2 finish, the following additional requirements shall apply.

A.1.1 Finishes required on F1 surfaces shall be uniformly and consistently maintained with no variation in the colour or consistency of the concrete within the same structure. In order to achieve this, the Contractor shall make trial panels of the formed finishes specified. Panels shall be not less than 1.5 m high and 1 m wide and 250 mm thick and shall be cast in accordance with the method and materials as proposed for the actual Work.

A.1.2 The Contractor shall provide at his own expense as many panels as required by the Engineer until a satisfactory trial panel has been accepted by the Engineer. These shall include samples of piers, deck sections, retaining wall sections and/or underpass wall sections and typical precast edge unit to be cast on site using the same method as proposed for the prototypes. The Contractor shall submit to the Engineer and obtain his approval all details before commencement of trials. These samples, when approved, shall form the standard against which the corresponding finishes on the actual work will be judged. In all cases of approvals, the decision of the Engineer shall be final.

A.1.3 Samples and trial panels carried out at the place of manufacture to demonstrate to the Engineer that the forms and formliners and the methods of assembling and de-shuttering them are acceptable shall not be paid for and will not relieve the Contractor of the requirement for carrying out trial panels on site as described above.

A.1.4 If the required finish in the opinion of the Engineer, has not been obtained in the Works, the Contractor shall promptly carry out at his own expense all measures required by the Engineer to obtain the specified finish. These may include grit blasting followed by the application of polyester or epoxy paint. Where such remedial action is ordered by the Engineer, the entire exposed surface shall be so treated irrespective of whether or not the defective areas are localised or extensive.

A.2 **Class F2.** Formwork shall be lined with a material approved by the Engineer to provide a smooth finish of uniform appearance. This material shall leave no stain on the concrete and shall be so joined and fixed to its backing so that it imparts no blemishes. It shall be of the same type and obtained from only one source for any one structure. The Contractor shall make good any imperfections in the finish as directed by the Engineer. Internal ties and embedded metal parts shall not be permitted unless otherwise approved by the Engineer.

A.3 **Class F3.** Irregularities in the finish shall be no greater than those resulting from the use of wrought thick square edged boards arranged in a uniform pattern. The finish is intended to be left as struck. Imperfections such as fins and surface discoloration shall be made good as and when required by the Engineer.

A.4 **Class F4.** No special requirements.

A.5 Permanently exposed concrete surfaces to classes F1, F2 and F3 finish shall be protected from rust marks and stains of all kinds. Internal ties and embedded metal parts are not permitted.

A.6 The Contractor shall submit to the Engineer all details of formwork, liners, joints, and materials including fabrication drawings and stating procedures involved in the use of formwork for approval before commencement of any work on fabrication. No formwork shall be brought to site without the prior approval of the Engineer. Adequate time shall be allowed by the Contractor in his programme for these approvals after consultation with the Engineer.

B. Unformed Finishes

B.1 Class U1. The concrete shall be uniformly levelled and screeded to produce a plain or ridged surface as described in the Contract. No further work shall be applied to the surface unless is used as the first stage for Class U2 or Class U3 finish.

B.2 Class U2. After the concrete has hardened sufficiently, the concrete Class U1 surface shall be floated by hand or machine sufficiently to produce a uniform surface free from screed marks.

B.3 Class U3. When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, a Class U1 surface shall be steel-trowelled under firm pressure to produce a dense, smooth uniform surface free from trowel marks.

5.04.6 TOLERANCES

A. The tolerances in the forms and formwork shall be such that members formed shall be within the tolerances for the size and type of the member specified elsewhere in the Specification.

B. Falsework shall be fixed such that the completed structure shall be within the required tolerances in plan, elevation and slope for the size and type of structure specified elsewhere in the Specification.

C. Surfaces which are to receive deck waterproofing shall be finished to an accuracy such that when tested with a three meter long straight edge, the maximum depression shall not exceed five mm.

5.04.7 CONSTRUCTION REQUIREMENTS

A. The forms and falsework shall be inspected by the Engineer after assembly on the work area and immediately before concreting. No pour shall commence until the forms and falsework have been approved by the Engineer.

B. The inside surfaces of all forms shall, except for pavement formwork, or unless otherwise agreed by the Engineer, be coated with a release agent approved by the Engineer. Release agents shall be applied strictly in accordance with the manufacturer's instructions and shall not come into contact with the reinforcement or prestressing tendons and anchorages. Only one type of release agent shall be used in formwork which will be visible in the finished work.

C. Immediately before concrete is placed, all forms shall be thoroughly cleaned.

D. Forms that are to be re-used shall be thoroughly cleaned and re-oiled and, if necessary, shall be reconditioned by revision or reconstruction. Unsatisfactory lumber shall be condemned by the Engineer and shall be removed from the Site.

E. Formwork shall be constructed so that the side forms of members can be removed without disturbing the soffit forms. If props are to be left in place when the soffit forms are removed, these props shall not be disturbed during the striking.

F. Runways used to move plant, equipment or materials shall be clear of the reinforcement and shall be robust enough not to deflect excessively or cause movement to the forms due to dynamic effects.

G. During concreting, the forms and their supports shall be constantly monitored for signs of imminent failure. Skilled operatives shall be in constant attendance during concreting who are qualified to make immediate adjustments to the forms and falsework so that concreting can satisfactorily be completed.

H. The Engineer shall suspend concreting operations if, in his opinion, the forms and falsework are in danger of failure and that the actions taken by the Contractor is insufficient or inadequate to guarantee the safe and satisfactory completion of concreting. In such an event, the Engineer shall instruct the Contractor to remove, at his expense, the concrete already poured.

I. If at any period of work, during or after placing of concrete, the forms show signs of sagging or bulging, the Contractor, at his own expense, shall remove the concrete to the extent directed by the Engineer, bring the forms to the proper position, and place concrete.

J. Immediately after the removal of the forms, all fins caused by form joints and other projections shall be removed and all pockets cleaned and filled with a cement mortar composed of 1 part by volume of Portland cement and 2 parts sand. Sufficient white Portland cement shall be mixed with the cement in the mortar, so that when dry the colour matches the surrounding concrete. Patches shall be moistened prior to mortaring to obtain a good bond with the concrete. When directed by the Engineer, the Contractor shall at his own expense, substitute an approved epoxy grout for the Portland cement mortar or provide an epoxy bonding agent to be used in conjunction with the Portland cement mortar. If, in the judgement of the Engineer, pockets are of such extent or character as to materially affect the strength of the structure or to endanger the life of the steel reinforcement, he may declare the concrete defective and require the removal and replacement of that portion of the structure affected. The resulting surfaces shall be true and uniform. Portions of the structure which cannot be finished or properly repaired to the satisfaction of the Engineer shall be removed.

5.04.8 REMOVAL OF FORMWORK AND FALSEWORK

A. To facilitate finishing, forms on handrails, ornamental work, and other vertical surfaces that require a rubbed finish, shall be removed as soon as the concrete has hardened sufficiently that it will not be injured, as determined by the Engineer. In determining the time for the removal of forms, consideration shall be given to the location and character of the structure, weather and other conditions influencing the setting of the concrete.

B. Formwork shall be removed without causing damage to the concrete and after sufficient time to allow for adequate curing and to prevent restraint that may arise from elastic shortening, shrinkage or creep.

C. Any remedial treatment to surfaces shall be agreed with the Engineer following inspection immediately after removing the formwork and shall be carried out without delay. Any concrete surface which has been treated before being inspected by the Engineer shall be liable to rejection.

D. Where the concrete compressive strength is confirmed by tests on concrete cylinders (or cubes) stored under conditions approved by the Engineer, formwork supporting concrete in bending may be struck when the strength is 10 N/sq. mm or three times the stress to which it will be subjected, whichever is the greater.

E. For ordinary structural concrete made with ordinary Portland cement, in the absence of control cylinders (cubes) the period before striking shall be in accordance with the minimum periods given in Table 5.4.2 unless otherwise directed by the Engineer.

TABLE 5.4.2: MINIMUM PERIOD BEFORE STRIKING FOR STRUCTURAL CONCRETE MADE WITH ORDINARY PORTLAND CEMENT

Type of Formwork	**Minimum Period before striking at Surface Temperature of Concrete**		
	16°C	**7°C**	**t°C**
Vertical formwork to columns, walls and large beams	12 hours	18 hours	$\frac{300}{(t + 10)}$ hours
Soffit formwork to slabs	4 days	6 days	$\frac{100}{(t+10)}$ days
Props to slabs	10 days	15 days	$\frac{250}{(t+10)}$ days
Soffit to formwork to beams	9 days	14 days	$\frac{230}{(t+10)}$ days
Props to beams	14 days	21 days	$\frac{360}{(t+10)}$ days

5.04.9 MEASUREMENT

A. The provisions of this section of the Specification are not measured directly for payment but shall be considered subsidiary to the different classes of concrete described and measured for payment under the provisions of Section 5.01 "Concrete and Concrete Mixes and Testing" of the Specification.

B. Test panels carried out by the Contractor to demonstrate to the Engineer's satisfaction that the specified F1 finish can be achieved shall be measured for payment for the appropriate class of concrete measured for payment under the provisions of Section 5.01 "Concrete and Concrete Mixes and Testing" of the Specification. Test panels not accepted by the Engineer shall not be measured for payment.

C. Test samples, such as a section of retaining wall or a complete pier, carried out by the Contractor and approved by the Engineer for use as reference bench marks for the quality to be attained in the Works shall be measured for payment for the appropriate class of concrete measured for payment under the provisions of Section 5.01 "Concrete and Concrete Mixes and Testing". Test samples not accepted by the Engineer shall not be measured for payment.

SECTION 5.06: PLAIN AND REINFORCED CONCRETE STRUCTURES

5.06.1 SCOPE

This Section of the Specification describes the construction of plain and reinforced concrete structures.

5.06.2 MATERIALS

A. Concrete

Concrete shall be produced and supplied in accordance with Section 5.01: Concrete Mixes and Testing.

B. Reinforcement

Reinforcement shall conform to Section 5.03: Steel Reinforcement.

C. Formwork and Falsework

Formwork and Falsework shall be designed and supplied in accordance with Section 5.04: Formwork and Falsework.

D. Plant and Equipment

Plant and Equipment shall conform with the requirements of the Specifications Part 1 Section 4-4 and shall be the type and number outlined in the Contractor's detailed Programme of Works as approved by the Engineer.

5.06.3 CONSTRUCTION

A. General

A.1 The Contractor shall notify the Engineer his intention to concrete at least 24 hours in advance.

A.2 The Engineer shall check and certify that:

- The formwork meets the Specification requirements
- The falsework and support props are in accordance with the approved Drawings.
- The reinforcement conforms to the Drawings and that the correct cover has been provided
- The forms are free of dirt and other deleterious matter.

B. Concreting

Handling, placing and curing shall be in accordance with Section 5.02: Concrete Handling, Placing and Curing.

C. Slump

Slump shall be within the limits given in Section 5.02 of the Specification except that the maximum slump of bridge deck superstructure concrete shall be 75 mm, unless otherwise agreed by the Engineer.

D. Construction and Expansion Joints

D.1 Whenever placing of concrete is delayed until after the previously placed concrete has undergone initial set, the point of the break in pouring shall be deemed a construction joint. The location of construction joints shall be either as shown on the Drawings or planned in advance and the placing of concrete shall be carried out continuously from joint to joint. The joints shall be perpendicular to the principal lines of stress and at points of minimum shear unless otherwise agreed with the Engineer.

D.2 Where dowels, reinforcing bars or other ties are not indicated on the Drawings, keys shall be made by embedding water-soaked bevelled timbers in workable concrete. The keys shall be sized as detailed on the Drawings or as directed by the Engineer and shall be removed when the concrete has set. When resuming work the surface of the concrete previously placed shall be thoroughly cleaned of dirt, scum, laitance or other soft material with stiff wire brushes and, if deemed necessary by the Engineer, shall be roughened with a steel tool. The surface shall then be thoroughly washed with clean water and pointed with a thick coat of neat cement mortar, after which the concreting shall proceed.

D.3 Expansion joints shall be manufactured and installed in accordance with the Drawings or as approved by the Engineer.

E. Cold Joints

E.1 When the continuous placement of concrete in any structural member is interrupted or delayed for a period long enough for the previously partially placed concrete to take its initial set, the Engineer shall declare such a joint a cold joint in which case the Contractor shall immediately remove the previously partially placed concrete from the forms. No extra payment shall be made for the initial placement or the removal of concrete that is wasted because of a cold joint. The Engineer shall suspend all or any part of the subsequent concrete work until he deems the Contractor has corrected the cause for the cold joint occurrence.

E.2 The Engineer shall, in certain circumstances, allow the Contractor to retain the partially placed concrete and complete the concreting with a subsequent pour. If the Engineer allows a cold joint to be retained, the Contractor shall carry out, at his own expense, some or all of the following measures to the satisfaction of the Engineer before completing the pour:

E.2.1 Laitance shall be removed from the surface of the partially placed concrete without damage to reinforcement and formwork by wire brushing, light tooling or sand blasting as agreed with the Engineer.

E.2.2 Shear keys shall be cut in the partially placed concrete without damage to the reinforcement and formwork. The shape, size and orientation of the shear keys shall be as directed by the Engineer.

E.2.3 The cleaned surface of the partially placed concrete shall be coated with a bonding agent approved by the Engineer, before placing the subsequent pour.

E.2.4 Additives approved by the Engineer to facilitate bonding shall be added to the concrete used for the subsequent pour.

E.2.5 Dowel bars of a type and length to be approved by the Engineer shall be installed in the partially placed concrete using non-shrink cement grout or resin grout as directed by the Engineer. The size and spacing of the dowel bars shall be approved by the Engineer. Their installation shall not damage the reinforcement or formwork.

E.2.6 The partially placed and subsequently placed concrete shall be stressed using prestressing bars of a size and type approved by the Engineer to achieve a level of compressive stress at the interface approved by the Engineer. The method of installing the prestressing bars and type of anchors used shall be approved by the Engineer. Unless otherwise agreed with the Engineer, the drill hole shall be grouted with a cement grout containing expanding additive to the manufacturer's recommendations.

F. Finishing

F.1 Unless otherwise indicated in the Drawings or agreed by the Engineer, the following classes of finishes, as defined in Paragraph 5.04.05, shall be used for formed surfaces:

F.1.1 Pre-cast parapets, cladding panels, New Jersey Barriers, wall copings and other architectural features: **Class F1**

F.1.2 Exposed faces of retaining walls, abutments, piers, columns, bridge decks and box culverts not in contact with soil and which can be seen : **Class F2**

F.1.3 Backs of retaining walls and solid abutments, outer faces of box culverts, faces of abutment columns and bases of bank seats for spill-through abutments, plinths for columns, piers, lighting masts and sign gantries in permanent contact with soil: **Class F3**

F.1.4 Inner faces of box girders, cellular deck slabs, cellular bases and pile caps not in contact with earth and which are not visible: **Class F3**

F.1.5 Sides of bases, footings and pile caps permanently below finished ground level: **Class F4**

F.2 Unless otherwise noted in the Drawings, the following classes of finishes, as defined in paragraph 5.04.5, shall be used for unformed surfaces:

F.2.1 Tops of bases, footings, pile caps and box culverts, which are to be backfilled: **Class U1**

F.2.2 Top of walls and slab which are to receive coping or tiling: **Class U2**

F.2.3 Box culvert inverts, apron slabs of box culverts and tops of exposed walls and slabs: **Class U3**

F.3 Finish to bridge decks that are to receive an approved waterproof system shall initially be finished to Class U1. When the concrete has sufficiently hardened to prevent laitance being worked to the surface the surface shall be floated to produce a uniform surface free from screed marks and exposed aggregate. The surface shall then be textured by brushing or otherwise in accordance with the waterproofing manufacturer's requirements and as agreed with the Engineer. The accuracy of the finished surface shall be such that it does not deviate from the required profile by more than 10 millimetres over a 3 metre gage length or have any abrupt irregularities of more than 3 millimetres.

F.4 Surfaces, other than bridge decks, which are to receive approved waterproofing systems, shall be finished to Class U2, unless otherwise detailed on the Drawings or as instructed by the Engineer.

G. Concrete Cover to Reinforcement

G.1 The concrete cover to reinforcement shall be as shown on the Drawings. If no cover is detailed the cover shall be either the size of the bar or the maximum aggregate size, plus 5 mm, whichever is the greater. In the case of bundled bars, the cover shall be equal to or greater than the size of a single bar of equivalent area of the bundle plus 5 mm.

G.2 Where a surface treatment such as grooved finish or bush hammering cuts in to the face of the concrete, the depth of the treatment shall be added to the cover.

G.3 The cover to reinforcement shall take into account the concrete durability under the envisaged conditions of exposure. The minimum cover to reinforcement under such conditions shall be determined by Engineer on site.

H. Tolerances

H.1 In-Situ Construction

H.1.1 Length: The horizontal and vertical dimensions of in-situ concrete members, except cross-sections, shall be within the following tolerances:

Length (mm)	Tolerance (mm)
Up to 3000	± 3
3001-4500	± 6
Vertical lines out of plane	± 5 + 1 for every 3000 out of true line.

H.1.2 Cross-Section: Slab and wall thicknesses and the cross-sectional dimensions of beams, columns and piers shall be within the following tolerances:

Member Dimensions (mm)	Tolerance (mm)
Up to 500	6
501 -750	10
Additional for every subsequent 100 mm	±1 mm up to ±20 mm

H.2 Precast Construction

H.2.1 Length: The horizontal and vertical dimensions of precast members, except for cross-sections, shall be within the following tolerances:

Length (mm)	Tolerance (mm)
Up to 3000	± 2
3000 and over	± 5

H.2.2 Cross Section: Slab and wall thicknesses and the cross-sectional dimensions of beams, columns and piers, shall be within a tolerance of ± 3 mm.

H.3 Squareness

For in-situ and pre-cast construction the tolerance between the short side and the long side shall be within the following limits:

Member Size (mm)	Tolerance (mm)
Up to 3000	± 3
3000 and over	± 6

H.4 Straightness

For in-situ and precast construction the straightness or bow, defined as deviation from the intended line, shall be within the following tolerances:

Member Length (mm)	Tolerances (mm)
Up to 3000	± 3
3000 and over	± 6

H.5 Alignment

The alignment of members shall be within the following tolerances:

Column and piers: 1:400 of column or pier length.

Others: 1:600 of length.

H.6 Flatness

The flatness of a surface, measured with a 1.5 metre straight edge shall be not greater than 6 mm at any point.

H.7 Twist

Twist, measured as the deviation of any corner from the plane containing the other three corners, shall be within the following limits.

Member Length (mm)	Tolerance (mm)
Up to 6000	6
Above 6000	12

5.06.4 MEASUREMENT

The provisions of this Section of the Specification are not measured directly for payment but shall be considered subsidiary to the different classes of concrete described and measured for payment under the provisions of Section 5.01: Concrete and Concrete Mixes and Testing.

SECTION 5.15 WATERPROOFING FOR STRUCTURES

5.15.1 SCOPE

The work covered in this Section consists of furnishing and placing approved waterproofing membranes and damp-proofing courses to external concrete surfaces in contact with soil, furnishing and placing epoxy coatings to internal surfaces of concrete walls, slabs and beds and furnishing and installing waterstops to waterproof construction and expansion joints; all as shown on the Drawings or as directed by the Engineer.

5.15.2 MATERIALS

A. Asphalt

A.1 Waterproofing asphalt shall conform to the Specification for Asphalt for Dampproofing and Waterproofing, AASHTO M115 (ASTM D449). Type I asphalt shall be used below ground and Type II above ground.

A.2 Primer for use with asphalt in waterproofing shall conform to the Specification for Primer for Use with Asphalt in Dampproofing and Waterproofing, AASHTO M116 (ASTM D41).

B. Bitumen

B.1 Waterproofing bitumen shall conform to the Specification for Coal-Tar Bitumen for Roofing, Dampproofing and Waterproofing, AASHTO M118 (ASTM D450). Type II waterproofing bitumen shall be provided unless otherwise specified in the Drawings.

B.2 Primer for use with coal-tar bitumen in dampproofing and waterproofing shall conform to the Specification for Creosote for Priming Coat with Coal-Tar Pitch in Dampproofing and Waterproofing, AASHTO M121 (ASTM D43).

C. Fabric

Fabric shall conform to the Specification for Woven Cotton Fabrics Saturated with Bituminous Substances for Use in Waterproofing, AASHTO M117 (ASTM D173).

D. Self-Adhesive Polyethylene Sheeting

Self-Adhesive Polyethylene Sheeting shall be flexible, preformed waterproof membrane comprising strong, high-density polyethylene film with a self-adhesive rubber/bitumen compound and having the following minimum properties:

- Total thickness : 1.5 mm
- Weight : 1.6 kg/m^2
- Tensile strength : 42 N/mm^2
- Elongation : 210% longitudinally; 160% transversely.
- Tear resistance : 340 N/mm longitudinally; 310 N/mm transversely.
- Puncture resistance : 220 N/ 65 mm

E. Tar for Absorptive Treatment

Tar for absorptive treatment shall be a liquid water-gas tar that conforms to the following requirements:

- Specific gravity, 25/25^{o}C	1.030 to 1.100
- Specific viscosity at 40^{o}C (Engler), not more than	3.0
- Total distillate, percent by weight, to 300^{o}C, not more than	50.0 %
- Bitumen (soluble in carbon disulphide) not less than	98.0 %
- Water, not more than	3.0 %

F. Tar Seal Coat

Tar seal coat shall conform to the Specification for Tar for Use in Road Construction, AASHTO M52, Grade RTCB-5 (ASTM D490).

G. Joint Fillers

Filler for use in horizontal and vertical joints in waterproofing work shall be a straight refined oil asphalt conforming to the following requirements:

- **Flash Point:** Not less than 232^{o}C.
- **Softening Point:** 48.9^{o}C to 54.4^{o}C.
- **Penetration:** At 0^{o}C, 200 grams, 1 minute, not less than 15.
  At 25^{o}C, 100 grams, 5 seconds, 50 to 60.
  At 46^{o}C, 50 grams, 5 seconds, not more than 300.
- **Loss on Heating:** At 163^{o}C, 50 grams, 5 hours, not more than 0.5 percent.
- **Ductility:** At 25^{o}C, 5 centimetres per minute, not less than 85.
- **Total Bitumen:** (soluble in carbon disulphide)**:** not less than 99.5 percent.

H. Waterstops

H.1 **PVC Water Bars** shall be extruded PVC, heavy duty, of the types and sizes shown on the Drawings, and complete with junction pieces.

H.2 **Copper Water Stops** shall be copper sheets of the thickness shown on the Drawings and shall conform to the requirements of AASHTO M138 (ASTM B152).

H.3 **Plain Rubber Water Stops** shall be formed from stock composed of a high grade compound made exclusively from new plantation rubber, reinforcing carbon black, zinc oxide, accelerators, anti-oxidants and softeners. This compound shall contain not less than 72 % by volume of new plantation rubber. The tensile strength shall be not less than 246 kg/cm^2, with an elongation at breaking of 550% when tested in accordance with ASTM D412. The unit stresses producing 300% and 500% elongation shall be not less than 77 kg and 198 kg/cm^2, respectively. The Shore Durometer indication (hardness) shall be between 55 and 65 when tested in accordance with ASTM D676. After 7 days in air at 126 ^{o}C (plus or minus 1 ^{o}C) or after 48 hours in oxygen at 126^{o}C (plus or minus 1^{o}C) both at 21kg/cm^2, the tensile strength and elongation shall not be less than 65 % of the original when tested in accordance with ASTM D572.

H.4 **Synthetic Rubber Water Stops** shall be formed from a compound made exclusively from neoprene, SBR, reinforcing carbon black, zinc oxide, polymerization agents and softeners. This compound shall contain not less than 70 percent by volume of neoprene or SBR. The tensile strength shall be not less than 175kg per square centimetre with an elongation at breaking of 425 % when tested in accordance with ASTM D412. The Shore Durometer Indication (hardness) shall be between 50 and 70 when tested in accordance with ASTM D676. After 7 days in air at 126 ^{o}C (plus or minus 1 ^{o}C) or after 48 hours in oxygen at 126 ^{o}C (plus or minus 1 ^{o}C) and 21kg kg/cm^2 pressure, the tensile strength shall be not less than 65 % of the original when tested in accordance with ASTM D572.

I. Proprietary Waterproofing Systems

Proprietary waterproofing systems shall be bituminous membranes reinforced with layers of suitable reinforcement, bituminous-coated polythene sheet, plasticized polyvinyl chloride sheet, other approved membranes or applications of resinous reinforced coatings. The type to be used shall be defined on the Drawings and shall be chosen according to its location and serviceability. The specific system shall be approved after site trials, should the Engineer decide these to be necessary.

J. Epoxy Coating System

An approved epoxy coating system shall be furnished and applied to the internal concrete surfaces of culverts and open channels as shown on the Drawings or as directed by the Engineer. The thickness of the epoxy coating shall be at least 400 (microns) in accordance with the manufacturer's recommendations.

5.15.3 SURFACE PREPARATION

A. Waterproofing

A.1 All concrete surfaces to be waterproofed shall be reasonably smooth and free from projections or holes which might cause puncture of the membrane. The surface shall be dry to prevent the formation of steam when the hot asphalt or tar is applied. Immediately before the application of the waterproofing, the surface shall be thoroughly cleaned of dust, projecting tying wire and loose material.

A.2 No waterproofing shall be carried out in wet weather or when the temperature is below 4 ^{o}C, without special authorisation from the Engineer. Should the surface of the concrete become temporarily damp, it shall be covered with a 2-inch (50mm) layer of hot sand, which shall be allowed to remain in place from 1 to 2 hours or sufficiently long enough to produce a warm and surface-dried condition, after which the sand shall be swept back, uncovering a sufficient surface for commencement of work and the operation repeated as the work progresses.

B. Dampproofing

The surface to which the damp-proofing coating is to be applied shall be cleaned of all loose and foreign material and dirt and shall be dry. If necessary, the Engineer shall instruct the surface to be scrubbed with water and a stiff brush, after which the surface shall be allowed to dry before application of the primer.

5.15.4 INSPECTION, DELIVERY AND STORAGE

A. All waterproofing materials shall be tested before shipment. Unless otherwise ordered by the Engineer, they shall be tested at the place of manufacture and, when so tested, a copy of the test results shall be sent to the Engineer by an agreed chemist or inspection bureau. Each package shall have affixed to it a label, seal, or other mark of identification, showing that it has been tested and found acceptable. The label shall identify the laboratory tests undertaken.

B. After delivery of the materials, representative check samples shall be taken which shall determine the acceptability of the materials.

C. All materials shall be delivered to the work in original containers, plainly marked with the manufacturer's brand or label.

D. Waterproofing and damp-proofing material shall be stored in a dry, protected place. Rolls of waterproofing fabric and membranes shall not be stored on end.

5.15.5 CONSTRUCTION

A. Asphalt and Bitumen Waterproofing Membranes

A.1 Asphalt shall be heated to a temperature between 150 ^{O}C and 175 ^{O}C and tar for hot application shall be heated to a temperature between 95 ^{O}C and 121 ^{O}C with frequent stirring to avoid local overheating. The heating kettles shall be equipped with thermometers.

A.2 In all cases, the waterproofing shall begin at the low point of the surface to be waterproofed, so that water will run over and not against or along the laps.

A.3 The first strip of fabric shall be of half-width; the second shall be full-width, lapped the full-width of the first sheet; and the third and each succeeding strip shall be full-width and lapped so that there will be two layers of fabric at all points with laps not less than 5 cm wide. All end laps shall be at least 30 cm.

A.4 Beginning at the low point of the surface to be waterproofed, a coating of primer shall be applied and allowed to dry before the first coat of asphalt is applied. The waterproofing shall then be applied as follows.

A.5 Beginning at the low point of the surface to be waterproofed, a section of 50 cm wide and to the full length of the surface shall be mopped with the hot asphalt or tar and, immediately following mopping, the first strip or half width of fabric shall be carefully pressed into place eliminating all air bubbles. The applied strip and the adjacent section of the surface of a width equal to slightly more than half of the width of the fabric being used shall then be mopped with hot asphalt or tar and a full width of fabric applied, completely covering the first strip, and pressed into place. The second strip and an adjacent section of the concrete surface shall then be mopped with hot asphalt or tar and the third strip of fabric applied, lapping the second strip by at least 5 cm. This process shall be repeated until the entire surface is covered with each strip of fabric lapping at least 5cm over the previous strip. The entire surface shall then be given a final mopping of hot asphalt or tar.

A.6 The completed waterproofing shall be a firmly bonded membrane composed of two layers of fabric and three moppings of asphalt or tar, together with a coating of primer. All layers of fabric shall be separated or covered by layers of asphalt or tar.

A.7 Mopping on concrete shall cover the entire surface with no concrete showing and applied on cloth sufficiently heavy to completely conceal the weave. On horizontal surfaces, not less than 50 litres of asphalt or tar shall be applied for each 10m^2 of finished work, and on vertical surfaces not less than 60 litres per 10 m^2 shall be applied. The work shall regulated to ensure that at the close of a day's work, all cloth that is laid shall have received the final mopping of asphalt or tar. All laps shall be thoroughly sealed.

A.8 At the edges of the membrane and at any point where it is punctured by drains or pipes, suitable provision shall be made to prevent water ingress between the waterproofing and the waterproofed surface, to the satisfaction of the Engineer.

A.9 All flashing at kerbs and against girders, spandrel walls, etc. shall be applied using separate sheets overlapping the main membrane by at least 30 centimetres. Flashing shall be closely sealed either with metal counter-flashing or by the embedment of the upper edges of the flashing in a groove full of joint filler.

A.10 Open joints other than expansion joints shall be caulked with oakum and lead wool and then filled with hot joint filler.

A.11 Expansion joints, both horizontal and vertical, shall be provided with sheet copper or lead in "U" or "V" forms in accordance with the Drawings. After the membrane has been placed, the joint shall be filled with hot joint filler. The membrane shall be carried continuously across all expansion joints.

A.12 At the ends of the structure the membrane shall be carried down on the abutments and suitable provision made for all movement.

B. Proprietary Waterproofing Membranes

Proprietary waterproofing membranes shall be installed strictly in accordance with the manufacturer's instructions and shall be laid so that no air is trapped between it and the concrete surface or between successive layers of sheeting. Unless otherwise specified, joints between sheets shall be lapped with end laps of at least 150 mm and side laps of at least 100 mm. The joints shall be arranged so that there are no more than three thicknesses of sheeting and so that water will drain away from the exposed edge.

C. Damage Patching of Waterproofing Membranes

C.1 Finished membranes shall be protected against damage and unnecessary contact. Any damage shall be repaired by patching. Patches shall extend at least 300 mm beyond the outermost damaged portion and the second application shall extend at least 75 mm beyond the first.

C.2 Proprietary waterproofing membranes shall be repaired according to the manufacturer's specifications and as directed by the Engineer.

D. Dampproofing

D.1 Concrete, brick or other surfaces to be protected by dampproofing shall be thoroughly cleaned before the primer is applied. Surfaces shall then be brush- or spray-painted with two or more coats of tar or asphalt for absorptive treatment as indicated on the Drawings or instructed by the Engineer. Dampproofing below ground level shall consist of not less than two coats at an application rate of 0.6 litres per square metre per coat. Above ground level one application of tar or asphalt seal coat shall be applied by brush, at an application rate of 0.5 litres per square metre.

D.2 Paints shall be applied to the areas to be waterproofed only. Any disfigurement of any other parts of the structure by dripping or spreading of the tar or asphalt shall be cleaned at the Contractor's expense to the Engineer's approval.

E. Protection of Waterproofing and Dampproofing

E.1 The waterproofing membrane and dampproofing courses shall be protected by a 50 mm course of mortar mixed in the proportion of one part Portland cement and two parts sand, unless otherwise shown on the Drawings. This mortar course shall be reinforced midway between its top and bottom surfaces with wire netting of 0.15m mesh and No. 12 gauge, or its equivalent. The top surface shall be trowelled to a smooth, hard finish true to grade.

E.2 The construction of the protection course shall follow the application of waterproofing within 24 hours.

E.3 Unless otherwise shown on the Drawings or directed by the Engineer, vertical faces either waterproofed or dampproofed shall be protected by a porous concrete block wall of not less than 225mm thickness or a proprietary synthetic sheeting if approved by the Engineer.

F. Water Stops

F.1 **Copper Water Stops:** Copper sheets for water stops shall be of the width specified and shall be bent to the shapes shown on the Drawings or instructed by the Engineer. The sheet copper in each joint shall be continuous; separate pieces being connected by thoroughly workmanlike soldered joints to form a complete watertight unit. The sheet copper shall be placed to ensure its embedment in the concrete on each side of the joint in the positions shown on the Drawings.

F.2 **Rubber Water Stops:** Rubber water stops shall be installed in accordance with the details shown on the Drawings. The water stops shall be formed with an integral cross section which shall be uniform within 3mm in width and the web thickness or bulb diameter, within plus 1.5mm and minus 0.75mm. No splices shall be permitted in straight strips. Strips and special connection pieces shall be well cured and all cross sections shall be dense, homogenous and free from all porosity. All junctions in the special connection pieces shall be fully moulded. During the vulcanizing period the joints shall be securely held by suitable clamps. The material at the splices shall be dense and homogenous throughout the cross section. Field splices shall be either vulcanized, mechanical, using stainless steel parts or made with a rubber splicing union of the same stock as the water stop. All finished splices shall demonstrate a tensile strength of not less than 50 % of the unspliced material.

G. Testing

Unless otherwise agreed by the Engineer, at least one site trial application of the waterproofing system shall be carried out to determine the suitability of the surface preparation, method of application and effectiveness of the protective layer. The size of membrane laid shall be not less than 2.0 metres wide and 5.0 metres long.

5.15.6 MEASUREMENT

A. Waterproofing membrane shall be measured by the square metre laid, completed and accepted for different types of waterproofing membranes.

B. Tar or bituminous painting to surfaces permanently in contact with backfilled material shall be measured by the square metre of surface area so painted, irrespective of the number of coats of paint specified.

C. Water stops shall not be measured for direct payment but shall be deemed to be included in the rates for concrete.

D. Protection to waterproofing membrane and dampproofing courses shall not be measured for direct payment but shall be deemed to be included in the rates for waterproofing and dampproofing.

E. Site trials of waterproofing membranes shall not be measured for direct payment but shall be deemed to be included in the rates for waterproofing.

F. The amount of completed and accepted work measured as provided above shall be paid at the unit price bid as specified in the Bill of Quantities; these prices shall be full compensation for furnishing all materials, labour, equipment, tools, supplies and all other items necessary for the completion of the work.

SECTION 5.21: JOINTS, SEALERS AND FILLERS

5.21.1 SCOPE

This work covered in this Section consists of joint sealing materials and preformed expansion joint filler for use as and where shown on the Drawings or as directed by the Engineer.

5.21.2 MATERIALS: JOINT SEALING COMPOUNDS

A. Hot Type Joint Sealing Compounds

A.1 Composition

This type shall be a mixture of virgin synthetic rubber or reclaimed rubber, or a combination of the two, with asphalt plasticizers. Ground cured rubber scrap shall not be used.

A.2 Physical Requirements

A.2.1 The joint sealing compound, after heating and application, shall form a resilient and adhesive compound capable of effectively sealing joints in concrete against the infiltration of moisture and foreign material through repeated cycles of expansion and contraction. It shall be capable of being brought by heating to a uniform, smooth pouring consistency, free from lumps, and suitable for completely filling the joints without damage to the material. It shall not flow from the joints or be picked-up and tracked by vehicle tyres in summer temperatures.

A.2.2 The application temperature shall be at least 11 ^{o}C lower than the safe heating temperature. The safe heating temperature is defined as the highest temperature to which the material can be heated and still meet all requirements of the Specification. No sample of the material shall be tested until the manufacturer furnishes his recommended safe-heating and pouring temperatures.

A.2.3 **Prolonged Heating:** After 6 hours of continuous heating, with constant mixing in the laboratory at the manufacturer's recommended pour temperature, the joint sealer shall meet all requirements of the Specification.

A.2.4 **Penetration:** The penetration at 25 ^{o}C, 150 g, 5 sec, shall not be less than 50 or more than 90 mm.

A.2.5 **Flow:** The flow at 60 ^{o}C and at a 75-degree angle shall not exceed 1 cm in 5 hours.

A.2.6 **Ductility:** Ductility at 25 ^{o}C shall be not less than 35 cm.

A.2.7 Bond: The hot type joint sealing compound material when tested at minus 17.8 ^{o}C to 100 percent extension (1.27 cm extended to 2.54 cm) shall, after 5 cycles, show no surface checking, cracking, separation or other opening in the material or between the material and the block. At least 2 test specimens in a set of 3 specimens representing a given sample shall meet this requirement.

A.2.8 Resilience: Recovery shall be not less than 25 percent.

A.2.9 Compression recovery: Compression recovery of bond specimens shall be not less than 1 cm within 15 min.

A.2.10 Impact: No failure in cohesion or adhesion shall occur.

A.3 Methods of Sampling and Testing

A.3.1 Sampling: Samples for testing shall consist of not less than a 4.5 kilogram sample from each batch of the joint sealer. A batch shall be considered as all finished material manufactured simultaneously or continuously as a unit between the time of compounding and the time of packaging or placing in shipping containers. Each package or container shall be marked properly to indicate clearly the batch of which it forms a part. The material shall be sampled in accordance with the requirements of the "Standard Methods of Sampling Bituminous Materials" (ASTM Designation: D140) for solid materials in cakes.

A.3.2 Testing: Testing shall be in accordance with AASHTO T187 except that the tolerances on dimensions of test specimens, Article 6.3, shall be $\pm$ 0.13 cm and the temperature tolerances, Article 6.4 shall be $\pm$ 2.2 ^{o}C.

B. Cold Type Joint Sealing Compounds

B.1 Composition

Cold type material shall be homogeneous and of such consistency that it can be applied by high-pressure pumps through suitable nozzles to completely fill the joints. The compound may be blended with a suitable solvent or solvents by the manufacturer to provide better workability during installation in the joints. The solvents shall be sufficiently volatile that they will evaporate within a short time after installation leaving a material that is adhesive and resilient.

B.2 Physical Requirements

B.2.1 Flow: The flow during a 5-hour period at 60 ^{o}C shall not exceed 0.5 cm.

B.2.2 Penetration: After evaporation of the solvent, the penetration at 25 ^{o}C, 150 gm, 5 sec, shall not exceed 220 mm.

B.2.3 Bond: When the compound is tested at minus 17.8 ^{o}C, the development at any time during the test procedure of a crack, separation or other opening which is at any point over 64 mm deep in the material or between the material and the concrete block, shall constitute failure of the test specimen. The failure of more than 1 test specimen in a group of 3 specimens, representing a given sample of joint sealing compound shall be cause for rejection of the sample.

B.3 Methods of Sampling and Testing

Cold-type joint compounds shall be tested in accordance with ASTM D1851, except that material for test specimens (Article 7(c)) shall be stirred manually rather than mechanically.

B.4 Preformed Joint Seals

Preformed Polychloroprene Elastomeric Joint Seals shall comply with the requirements of AASHTO M220 (ASTM D2628).

C. Movement Joints in Water Retaining Structures

Joint sealants for movement joints in water retaining structures shall be polysulphide based compounds to BS EN ISO 11600:2003 and approved by the Engineer.

D. Exposed Joint Sealants for Movement Joints

Exposed joint sealants for movement joints shall be polysulphide rubber based compounds unless otherwise specified and subject to approval by the Engineer.

E. Backing Strips for Movement Joints

Backing strips shall be of a type recommended by the joint sealant manufacturer and approved by the Engineer.

5.21.3 PREFORMED EXPANSION JOINT FILLER

A. Description

Preformed expansion joint filler shall be a non-extruding and resilient bituminous type and shall have relatively little extrusion and a moderate to high amount of recovery after release from compression.

B. Requirements

Non-extruding and resilient types of expansion joint filler shall conform to all the requirements of the Standard Specification for "Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types)", AASHTO Designation M213 (ASTM D1751).

C. Movement Joint Sheet Material Filler in Water Retaining Structures

Expansion joints in water retaining structures shall be bonded granular cork to ASTM D1752 or ASTM D1751 and as approved by the Engineer.

5.21.4 CERTIFICATE OF GUARANTEE

The Contractor shall furnish the Engineer with a Manufacturer's Certificate of Guarantee for each type of joint material delivered to the Site. The certificate shall note compliance to the appropriate specifications and shall state the results of the tests performed on the material, as required by the specifications. The Contractor shall, when so directed by the Engineer, have the joint material tested for conformance to the applicable specifications at an approved testing laboratory. All costs connected with Certificate of Guarantee and any subsequent quality testing shall be at the Contractor's expense.

5.21.5 CONSTRUCTION

A. Joints shall be straight, vertical, horizontal or as detailed on the drawings or approved by the Engineer. Joints shall be formed to accommodate any projecting reinforcement.

B. Movement Joints are either:

- Formed expansion joints
- Formed contraction joints
- Induced contraction joints.

C. Formed movement joints shall be constructed between rigid stop ends and formwork at formed movement joints to permit separate construction of structurally separate parts of the work.

D. The Contractor shall submit proposals for the positions of construction joints, where they are not coincident with movement joints, for approval by the Engineer.

E. To prepare for construction joints the face shall be lightly roughened to expose coarse aggregate unless otherwise instructed by the Engineer. The face shall be wetted and covered with a 1:1 cement and sand grout immediately prior to placing fresh concrete. Roughening shall not take place in areas less than 25 mm from arrises to surfaces exposed to view in the finished work. Small mortar lips shall be removed from exposed arrises using a carborundum stone. The face shall be clean and damp before fresh concrete is placed against it.

F. Side and end forms of concrete floors shall be square edged to the steel top surface.

G. External waterbars shall be nailed to forms prior to concreting and butt jointed in accordance with the manufacturer's instructions.

H. Movement joints shall be sealed strictly in accordance with the manufacturer's recommendations. Joints shall be thoroughly clean and dry, free from oil and loose material. Joint faces shall be wire brushed or grit blasted and cleaned out with compressed air. The joint faces shall then be allowed to dry. Exposed faces shall be have their edges masked with tape before priming and the tape removed immediately after sealing. Sealant shall be applied to ensure a maximum adhesion to the sides of the joints and a neat, smooth and clean finish.

5.21.6 MEASUREMENT

A. No part of this Section is a Bid Item and no measurement shall be made.

B. The materials provided for this Section will not be paid for directly, but will be considered included in the payment for other items of work appearing in the Bill of Quantities.