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SECTION TS 3. CONCRETE WORK

SECTION TS 3. CONCRETE WORK

3.1 GENERAL

3.1.1 Scope

This section of the Technical Specification covers the general and specific requirements of concrete. It relates to the concrete in the Asin Pumping Station, bridges, gate works, buildings, channel works, culverts, revetments and all other parts of the Works which contain concrete.

This section particularly covers the supply and mixing of materials, the forming, placing, curing and finishing of the concrete, the quality of concrete required, and the supply, handling and placing of steel reinforcement for concrete.

Special requirements for concrete with respect to prestressed, precast or other types of concrete are specified in the relevant sections of the Technical Specification.

3.1.2 Description of Concrete, Mortar and Grout

3.1.2.1 Concrete

Concrete shall be composed of water, cement, fine aggregate and coarse aggregate and of any admixture that may be specified or consented to by the Engineer.

The consistency is to be in accordance with Clause 3.2.5.2

Testing is to be witnessed by the Engineer unless otherwise directed by the Engineer.

3.1.2.2 Cement Mortars

Cement mortar shall be composed of one part of cement to one part of fine aggregate by volume, or such other proportions as shall be directed by the Engineer, or as shown on the Drawings but not exceeding three parts by volume of fine aggregate to one part of cement mixed with water so that the water-cement ratio does not exceed 0.45 by weight.

Stiff cement mortar shall be as above, but with a water-cement ratio not exceeding 0.35, or to a consistency consented to by the Engineer.

Dry pack cement mortar shall be as above, but with water just sufficient to ensure full hydration of cement.

Mix proportions for mortar for wet stone masonry are specified in the technical specification for wet stone masonry in this specification.

3.1.2.3 Grout

Grout for sealing prestressing tendon ducts of other purposes shall be composed of cement, fine aggregate, water and admixtures as consented to or directed by the Engineer. The proportion of fine aggregate in the mix shall be as determined by the Engineer, who may direct that it be omitted altogether. The admixtures may be expanding and/or flow promoting agents. If aluminium powder is used as an expanding agent, the proportion shall be fifty parts per million of the cement by weight and the powder shall be mixed

with ground pumice stone and/or dry cement prior to adding to the cement dry. The proportion and colour of the pumice used shall be as consented to by the Engineer and shall ensure that accurate and uniform mixing with the cement is obtained.

The water-cement ratio shall be between 0.40 and 0.50 by weight. When used for sealing ducts in prestressed concrete, the grout shall be mixed to the stiffest consistency that can be forced through the ducts at as pressure consented to by the Engineer, generally not more than 700 kPa (7 kg/cm^2).

Grout for sealing ducts shall not be fed to the grout pump until the whole batch is thoroughly mixed. The grout shall be free of lumps and shall be strained, using a suitable filter.

Where non-shrink grout is specified for use, the Contractor shall submit technical data of the particular product proposed to be used for the Engineer's review and approval.

3.1.3 Classes of Concrete

The class or strength grade of concrete used in each part of the Works shall be that called for on the Drawings or ordered by the Engineer.

Where not shown on the Drawings or ordered by the Engineer the use of each class of concrete shall be as shown in Table 3.1. Attention is drawn to the alternative notation for concrete class. The upper designation C1, D etc. refers to the notation shown on the drawing and in the Bill of Quantities whilst the lower designation (K250 etc) refers to the notation used throughout this specification and the Indonesian Concrete Code.

Table 3.1: Classes of Concrete

Class of Concrete	28-day Compressive Strength MPa	kgf/cm^2	Max. Size of Aggregate mm	Application
A-1 K500	50	500	-	Prestressed concrete piles from commercial suppliers
A-2 K400	40	400	25	Prestressed concrete for bridge beams and prestressed concrete piles
A-3 K350	35	350	25	Prestressed concrete slabs, precast concrete piles
B K250	25	250	25	Reinforced concrete bridge beams
C1 K225	22.5	225	25	General use for reinforced concrete
C2 K225	22.5	225	15	Secondary concrete for blockouts.
D K175	17.5	175	40	Plain concrete for structures
E K125	12.5	125	25	Plain concrete for levelling

The class of concrete is defined as the Characteristic Strength at 28 days as defined in the Indonesian Concrete Code, (PBI 71), for samples tested in accordance with the requirements of AASHTO T 22 (ASTM C 39) using standard cubes of 150 mm.

Air - entrained is not required unless called for in the Drawings.

3.1.4 Strength Requirements

The mean compressive strength of the concrete shall be determined on the specimens obtained in prepared in accordance with AASHTO T 141 (ASTM C 172) and AASHTO T 23 (ASTM C 31). Test specimens made and cured in the laboratory shall conform to AASHTO T 126 (ASTM C 192). The compression test shall be performed on specimens according to specification AASHTO T 22.

The Characteristic Strength of the various classes of concrete, an accordance with the Indonesian Concrete Code (PBI 71), is obtained as defined as being the strength below which only 5 percent of specimens fall for a minimum of 20 specimens tested.

The mean compressive strength of concrete after 28 days shall be equal to or greater than the sum of the relevant Characteristic Strengths, as shown in Table 3.2, plus the strength margin as defined in Clause 3.2.1.2 below, while the mean compressive strength at 7 (seven) days shall, unless otherwise shown on the Drawings or directed by the Engineer, be 75 % (seventy five percent) of the prescribed values at 28 (twenty eight) days.

Table 3.2- Strength Requirements

Classes of Concrete	Characteristic Strength at 28 days (kg/cm^2)	
	Cube[1]	Cylinder[2]
K500	500	-
K400	400	-
K350	350	290
K225	225	185
K175	175	145
K125	125	100

(1) Cube of 15 cm size (2) Cylinder of 15x30 cm size

3.2 SUPPLY AND DELIVERY OF CONCRETE

3.2.1 Mix Design

3.2.1.1 General

The concrete shall consist of a mixture of cement, fine aggregate, coarse aggregate and water.

The concrete may also contain admixtures where these have been consented to by the Engineer.

3.2.1.2 Target Strength

The concrete mix shall be designed for a target strength in excess of the specified Characteristic Strength. The target strength shall be selected

having regard to the degree of quality control which the Contractor can expect over the materials and handling of concrete in the field.

For water cured concrete the target strength shall not be less than T, where:

$$F_c = T - 1.64\ s$$

and F_c is the specified Characteristic Strength at 28 days, and is the standard deviation as defined below.

For other methods if curing the Contractor shall submit the method of calculation of T.

3.2.1.3 Standard Deviation

For classes of concrete with the Characteristic Strengths less than or equal to 35 MPa (350 kg/cm^2) the estimated standard deviation of the compressive strengths of the concrete produced shall not be less than 4.5 MPa (45 kg/cm^2) nor greater than 8.5 MPa (85 kg/cm^2).

For classes of concrete with the Characteristic Strengths above 35 MPa (350 kg/cm^2) the estimated standard deviation of the compressive strengths of the concrete produced shall not be less than 25 MPa (250 kg/cm^2) nor greater than 5.0 MPa (50 kg/cm^2).

The Contractor shall nominate the target strength for the Engineer's consent. The standard deviation shall be determined for the concrete batch plant used and shall allow for variability of materials, batching, mixing, sampling and delivery operations. The target strength nominated shall take into account that the characteristic minimum compressive strength of concrete is based on the testing of samples taken at the point of use. Table 3.3 may be used as an initial guide in the determination of the estimated standard deviation.

Table 3.3 – Initial Estimate of Standard Deviation

Job	Standard of Control	Estimated Standards Deviation (MPa) – (kg/cm^2)		Margin by which target should exceed specified strength (MPa) - (kg/cm^2)	
		F'c < 35 (MPa) – (350 kg/cm^2)	F'c > 35 (MPa) – (350 kg/cm^2)	F'c < 35 (MPa) - (350kg/cm^2)	F'c < 35 (MPa) - (350 kg/cm^2)
Weigh batching of all materials, aggregate moisture and slump checks, uniform materials, very good methods of transport and placement and complete freedom from contamination of the concrete, constant supervision.	Excellent (automated control)	3.5 – 4.5 (35-45)	2.5 – 3.5 (25-35)	6.0 – 7.5 (60-75)	4.0 – 6.0 (40-60)
Weigh batching of all material, slump checked, occasional changes in production and slump, good methods of transport and placing and regular supervision	Very Good	4.5 – 5.5 (45-55)	3.5 – 5.0 (35-50)	7.5 – 9.0 (75-90)	6.0 – 8.0 (60-80)
Weigh batching of all materials or volume batching of aggregates plus allowance for moisture bulking, regular supervision of mixing and placing of concrete	Fair	5.5 – 7.5 (55-75)	Not Applicable	9.0 – 12.0 (90-120)	Not Applicable

In the design of a mix the Contractor shall take into account the slump requirements and the grading and maximum size of aggregates specified.

3.2.1.4 Proportions of Mix

i. Design submitted by the Contractor

The Contractor shall submit to the Engineer for his consent details of the concrete mix design, including the water-cement ratio proposed to be used for each class of concrete. These details shall be supplied six (6) weeks in advance of placing that particular class of concrete in the work so as to permit strength test to be made from trial mixes. The trial mixes will be carried out using samples of the materials submitted, and in the proportions proposed, by the Contractor. Alternatively the Engineer may request the Contractor to prepare, at the Contractor's expense, a trial mix of each class of concrete proposed to be used incorporating only such materials as have been tested and their use consented to by the Engineer. The trial mixes shall be made in the presence of the Engineer or his representative using the plant and the degree of quality control proposed for the work. Each mix shall be tested for slump, workability and strength.

If the coarse aggregate of fine aggregate is composed of more than one material of size of material the mix proportions of each shall be specified separately. Samples of each type of material and/or each size of material shall also be supplied by the Contractor as specified in Clauses 3.2.2.2 and 3.2.2.3

The Proportions of the concrete mixes shall be designed by the Contractor to satisfy the specified requirements of strength, grading and consistency.

Unless otherwise specified or consented to the Engineer, slump, water cement ratio and cement content shall conform to the values in Table 3.3.

Table 3.4- Properties of Concrete Mix

Class	Characteristic Minimum Strength (MPa)		Minimum Cement Content 3) (kg/m^3)	Maximum Water/Cement Ratio by mass	Maximum Slump[4] (mm)
	Cube[1]	Cylinder[2]			
K125	12.5	10.0	200	0.60	100
K175	17.5	14.5	240	0.60	100
K225	22.5	18.5	280	0.60	100
K350	35.0	29.0	360	0.50	100
K400	40				
K500	50				

Note:

1) Compressive strength based on 150 mm cube

2) Compressive strength based on 150 mm diameter x 300 mm high cylinder.

Concrete to be paced under water shall have a minimum cement content of 400 kg/cm3.

Slump will be determined in accordance with Clause 3.2.5.2

The maximum cement content in any concrete mixture shall not exceed 450 kg/m^3.

ii. Trial Mix Results

Prior to consent being given to a mix by the Contractor its compressive strength and shrinkage at 28 days will be checked from trial mixes.

A minimum of 20 Specimens shall be cast for the purpose of ascertaining the compressive strength of the trial mix.

In the case of urgency or for mixes which contain special admixtures, or are stream cured the Engineer may give a provisional consent based on test at an earlier age than 28 days but tests at age 28 days shall be the basis of final consent.

After the Engineer has consented to the use of a certain mix design of a particular class of concrete this mix shall be used for the work. In the event of changes in either properties or sources of materials or in their relative proportions the Engineer may require changes in the proportion of the materials and further testing.

iii. Control of Mix During Contract

In order to determine any need for mix adjustment the progress of the work, a statistical check may be made of the compressive strength of concrete, using consecutive 28 days test result representing concrete placed in the work, and making separate checks of each mix.

For each separate class of concrete, the concrete mix and its method of productions will be considered satisfactory should the following requirements be met:

i. Not more than one specimen from a group of twenty (20) consecutive specimens shall have a compressive strength at 28 days less than the Characteristic Strength for that class of concrete.

ii. The average of compressive strength at 28 day of any four (4) consecutive specimen shall not be less than the Characteristic Strength for that class of concrete plus 0.82 times the standard deviation as defined below.

iii. The difference in the values of compressive strength at 28 days between the highest and lowest value of any four (4) consecutive specimen shall be less than 4.3 times the standard deviation defined below.

The standard deviation shall be taken as the initial estimate (Clause 3.2.1.3 refers) until 20 specimens from concrete in the structure have been tested. At this stage the value of standard deviation shall be calculated from the result of the 20 strength tests this review process shall be repeated after every successive 20 test result and the requirement i, ii, and iii above applied succeeding batches of concrete.

In any case the standard deviation shall not exceed 8.5 MPa (85 kg/cm^2) for classes of concrete with Characteristic Strengths less than or equal to 35 MPa (350 kg/cm^2) or 5.0 MPa (50 kg/cm^2) for classes of concrete with Characteristic Strength above 35 MPa (350 kg/cm^2).

Notwithstanding consent by the Engineer to a proposed mix, the Contractor shall be solely responsible for producing concrete with satisfies the requirements of this Specification.

Should the Contractor propose to place concrete by pumping and the design of a mix suitable for pumping requires cements additional to that specified above, the cost of the additional cement shall be borne by the Contractor.

3.2.2 Materials

3.2.2.1 Supply of Cement

Cement shall be supplied by the Contractor and shall conform to the requirements of AASHTO M 85 (ASTM C 150). The Contractor shall not use low heat cement (Type IV) unless ordered or consented to by the Engineer. Cement shall be from one manufacturer and of one brand, type and grind and shall not be changed during the duration of the Contract without the consent of the Engineer. Sulphate resistant cement shall comply with the requirements of AASHTO M 85 for Type II cement. High sulphate resistant cement (AASHTO M 85 Type V) shall not be used unless otherwise ordered or consented to by the Engineer.

High alumina cement (Ciment Fondu) shall not be used without the written consent of the Engineer.

Air Entraining cement shall only be used with the prior consent of the Engineer and shall comply with the requirements of AASHTO M 85 (ASTM C150) and this Specification.

Blast Furnace cements shall only be used with the prior consent of the Engineer and shall comply with the requirements of AASHTO M 240 (ASTM C 595) and this Specification.

Fly Ash shall only be used with the prior consent of the Engineer and shall comply with the requirements of ASTM C 618 "Specification for Fly Ash and Raw or Calcined Natural Pozzolans for use in Portland Cement Concrete" and this Specification.

When not otherwise specified, the Contractor may use any type of Portland cement conforming to AASHTO M 85 except type IV or type V. When an air-retraining type is used, the Contractor shall maintain a supply of non-air-retraining cement As well as air retraining admixtures, for use where adjustment of air content may be required.

Cement shall be used in the order in which it is received by the Contractor. Cement shall not be used in this Contract more than ten (10) weeks after the date of dispatch from the cement works. The quality of the cement may be tested at any time by the Engineer.

The Engineer will select the sample which shall be supplied by the Contractor, free of charge, in accordance with AASHTO T 1217 (ASTM C 183).

3.2.2.2 Fine Aggregate

Fine aggregate for concrete shall consist of natural sand or, subject to the consent of the Engineer, other inert materials with similar characteristics, having durable particles. Fine aggregate from different sources of supply shall not be mixed or stored in the same pile nor used alternatively in the same class of construction without the consent of the Engineer.

The fine aggregate shall not contain deleterious substances in excess of the following percentages:

Percentage	AASHTO Test method	by weight
Clay lumps	T 112	1
Coal and lignite	T 113	1
Material passing No. 200 (75 micron) sieve .	T 11	3

Materials which contain other deleterious substances (such as shale, alkali, mica, coated grains, soft and flaky particles) shall be subject to the Engineers review and approval.

When the fine aggregate is subjected to five alternations of the sodium sulphate soundness test, using AASHTO T 04 (ASTM C 88), the weighted percentage of loss shall be not more than 10 percent. Fine aggregate failing to meet the requirements for soundness may be accepted provided it can be shown by evidence satisfactory to the Engineer that concrete of comparable proportions made from similar aggregate from the same source has been exposed to similar conditions of weathering for a period of at least 5 years without appreciable disintegration. The requirements for soundness may be waived in the case of aggregate for use in structures or portions of structures not exposed of weathering.

All fine aggregate shall be free from injurious amounts of organic impurities. Aggregates subjected to the colorimetric test for organic impurities, AASHTO T 21 (ASTM C 40), and producing a colour darker than the standard shall be rejected unless they pass the mortar-strength test. Should the aggregate in tests conducted during progress of the work show a colour darker than that of samples originally approved for the work, its use shall be discontinued until tests satisfactory to the Engineer have been made to determine whether the increased colour is indicative of an injurious amount of deleterious substances.

Mortar specimens containing the fine aggregate, when tested according to AASHTO T 71 (ASTM C 87), shall develop a compressive strength at the age of 3 days, when using type III cement, or at 7 days when using type I or II cement of not less than 90 percent of the strength developed by a mortar prepared in the same manner with the same cement and graded Ottawa sand having a fineness modules of 2.40 $\pm$ 0.10. Type I, II and III cements shall conform to AASHTO M 85.

The fine aggregate shall be uniformly graded and shall meet the following grading requirements:

Sieve designation	**Percentage by weight passing square-mesh sieves (AASHTO T 27)**
3/8 inch	100
No. 4	95-100
No. 16	45-80
No. 50	10-30
No. 100	2-10

Fine aggregate failing to pass the minimum requirement for material passing the No. 50 and No. 100 sieves may be used provided an approved inorganic fine inert material is added to correct the deficiency in grading.

The gradation requirements given above are the extreme limits to be used in determining the suitability of material from all possible sources of supply. The gradation of materials from any one source shall not vary in composition beyond the range values that govern the selection of a source of supply. For the purpose of determining the degree of uniformity, a fineness modulus determination shall be made upon representative samples, submitted by the Contractor, from such sources as he proposes to use. Fine aggregate from any one source having a variation in fineness modulus greater than 0.20, plus or minus, from the average fineness modulus of the representative sample submitted by the Contractor shall be rejected or may be accepted subject to such changes in the proportion of the concrete or such changes in storing or loading of sands as the Engineer may direct.

The fineness modulus of fine aggregate shall be determined by adding the cumulative percentages, by weight, of material retained on each of U.S. Standard Sieves No. 4, 8, 16, 30, 50 and 100, and dividing by 100.

3.2.2.3 Coarse Aggregate

The coarse aggregate for concrete shall consist of crushed stone, gravel, blast-furnace slag, or other approved inert material of similar characteristics having durable pieces, free from undesirable adherent coatings.

Crushed stone or crushed gravel shall be used for class K250 and class K350 or stronger concretes.

Unless otherwise consented to by the Engineer, concrete in various parts of the structures shall contain coarse aggregate with the effective maximum sizes as shown in table 3.1.

The effective minimum size shall be ten (10) mm for crushed material and five (5) mm for rounded materials unless otherwise directed by the Engineer.

The coarse aggregate shall not contain deleterious substances in excess of the following percentages:

Percentage	AASHTO Test method	by weight
Clay lumps	T 112	0.25
Material passing No. 200 (75 m) sieve	T 11	1
Thin or elongated pieces (length greater than 5 times maximum thickness)....	-	10

Materials which contain other deleterious substances shall be subject to the Engineers review and approval.

The coarse aggregate shall not have a percentage of wear more than 50 at 500 revolutions as determined by AASHTO T 96 (ASTM C 131).

When the coarse aggregate is subjected to five of the sodium sulphate soundness test, using the samples described as alternate B of AASHTO T 104, the weighted percentage of loss shall be not more than 12 percent. Coarse aggregate failing to meet the requirement for soundness may be accepted provided it can be shown by evidence satisfactory to the Engineer that concrete of comparable proportions made from similar aggregates from the same source has been exposed to weathering under conditions similar to those occurring at the site of the structure for a period of at least 5 years without appreciable disintegration. The requirements for soundness may be

waived by the Engineer when the aggregate is to be used in structures or portions of structures not exposed to weathering.

Coarse aggregate shall conform to the requirements of Table 3.5 for sizes designated and shall be uniformly graded between the limits specified.

Lightweight aggregate, if required or permitted by the Special Specifications, shall conform to the requirements of AASHTO M 195 (ASTM C 330) for grading specified.

Table 3.5 – Requirement for Grading of Coarse Aggregate

Percentages by weight (AASHTO T 27)	Nominal Size Range								
	12 mm	19.5 mm	25 mm	37.5 mm	50 mm	62.5 mm	19 mm – 37.5 mm	25 mm – 50 mm	37.5 mm – 62.5 mm
75 mm						100			100
62.5 mm					100	95-100		100	90-100
50 mm				100	95-100	-	100	95-100	35-70
37.5 mm			100	95-100	-	35-70	90-100	35-70	0-15
25 mm		100	95-100	-	35-70	-	20-55	0-15	-
19 mm	100	90-100	-	35-70	-	10-30	0-15	-	0-5
12 mm	90-100	-	25-60	-	10-30	-	-	0.50	0
10 mm	40-70	20-55	10-30	-	-	0.5	-	-	-
4.75 mm	0-15	0-10	0-10	0-5	0-5	0-5	-	-	-
2.36 mm	0-5	0-5	0-5						

3.2.2.4 Admixtures

Admixtures may only be used if consented to by the Engineer and then only in such quantities and manner as he may consent to in writing.

Such admixtures shall conform with the requirements of:

- AASHTO M 194 (ASTM C 494) "Specification for Chemical Admixtures for Concrete":
  - Type A - Water-reducing
  - Type B - Retarding
  - Type C - Accelerating
  - Type D - Water-reducing and retarding
  - Type E - Water-reducing and accelerating
  - Type F - Water-reducing (high range) and
  - Type G - Water-reducing(high range) and retarding
- AASHTO M 154 (ASTM C 260) "Specification for Air-entraining Admixtures for Concrete".

Admixtures shall not reduce the strength of concrete below that specified. Shrinkage and dosage sensitivity characteristics will be taken into account, if relevant.

Admixtures shall not contain chlorides, chlorine, sulphides or sulphites, or any other substance which may be detrimental to concrete or steel.

Use calcium chloride or admixtures containing calcium chloride will not be permitted.

3.2.2.5 Water

Concrete shall not be mixed unless the water to be used is approved by the Engineer. Water shall meet the suggested requirements of AASHTO T 26. Water known to be of potable quality may be used without test. The water shall be clear, neither salty nor brackish and free of all substances harmful to concrete and reinforcement. Harmful substances include oils, organic substances, vegetable matter, acids, alkalis and dissolved salts. The amounts of chloride and chlorine in the water shall be not greater than 0.1 percent.

3.2.2.6 Rubble Stone

Stone for cyclopean concrete, mortar rubble, dry rubble masonry or wet stone masonry shall be of suitable quality, sound and durable, and free from segregation, seams, cracks and other structural defects, or imperfections tending to destroy its resistance to the weather. It shall be free from rounded, worn, or weathered surfaces. All weathered stone shall be rejected. The stone shall be kept free from dirt, oil or any other injurious material which may prevent the proper adhesion of mortar.

3.2.2.7 Samples and Tests

At least six (6) weeks prior to commencement of concreting and on request at any other time during the Contract, the Contractor shall prepare and make

available to the Engineer any or all of the following materials proposed to be used on the Contract:

1) A 50 kilogram sample of source rock from each source. The sample shall be in the form of spalls of 100 to 800 mm size.

2) A 30 kilogram sample of each component aggregate together with a statement of the proportions in which it is proposed to use them in concrete.

3) A 10 kilogram bulk sample of cement sampled in accordance with ASTM C 183, Methods of Sampling Hydraulic Cement.

4) A 5 litre sample of water.

Samples shall be supplied by the Contractor free of charge to the designated office or laboratory. Sampling procedure supplied for the above series of tests on aggregates shall be as set out in AASHTO T 2 (ASTM D 75). If so directed by the Engineer, additional quantities of aggregates shall be submitted for the preparation of trial mixes.

If the Contractor proposes to place concrete by pumping he shall advise the Engineer at the time he submits samples for testing.

During the progress of the work further deliveries of a previously accepted material will be accepted subject to their satisfactorily passing the requirements of Clause 3.2.2.2 and 3.2.2.3, and/or compressive tests of the designed concrete mix as specified in Clause 3.3.7

3.2.2.8 Handling and Storage

i. Aggregates

Concrete aggregates shall be stored on firm, relatively level well drained ground so as to prevent mixing of foreign materials with the aggregates. Aggregates shall be delivered to the plant in one or more separate size ranges corresponding to the constituents of the Submitted Samples and shall be stored in separate areas to avoid intermixing. Each aggregate shall be the product of a single screen and shall not be obtained by mixing two or more sizes.

ii. Cement

Bulk cement shall be stored in bins and silos which are weather and designed to allow complete discharge.

Bagged cement shall be stored clear of the ground in a waterproof building. Different types, brands and deliveries of a cement shall be stored and handled to avoid intermingling and contamination and so that the cement in used in the sequence received. Cement from bags which have split will be condemned.

Any cement that becomes contaminated, wet or otherwise defective will be condemned.

Cement condemned for any reason shall not be used in the work of this Contract and, if at the site of the works, shall be removed immediately from the works by the Contractor who shall bear all costs of its removal and replacement with fresh cement.

iii. Admixtures

Where the use of admixtures has been consented to buy the Engineer they shall be stored in such a manner as to prevent contamination or freezing.

Liquid admixtures shall be stored in containers which provide for adequate stirring prior to discharge into the concrete mixer.

3.2.3 Batching

3.2.3.1 Batching

Unless otherwise consented to by the Engineer the measurement and batching of materials shall be done at a batching plant.

All materials shall be measured by weighing except when volume batching is authorised in writing by the Engineer and liquid admixtures may be measured in adjustable liquid measuring device, and cement may be measured by bags as packed by the manufacturer, in which case batches shall be proportioned on the basis of one or more unbroken bags of cement.

Batch hoppers, scales, water meters and admixtures dispensers shall be capable individual materials to within one (1) percent. Certified tests of the accuracy of weighing and measuring equipment shall be carried out annually or as directed by the Engineer and the results made available for inspection by the Engineer.

3.2.3.2 Classification of Plants

The Contractor shall nominate, at the same time as the samples of material referred to in Clause 3.2.2.1 are furnished, the manufacturer and model number of the batch plant(s) proposed to be used for the production of concrete under this Contract. In addition the methods of batching and the quality control to be exercised shall also be supplied. If the Contractor proposes to use portable mixers he shall provide full details of the mixing plant.

Table 3.3 lists the classification of concrete mixing plants and the expected standard deviation of the compressive strength test results required under Clause 3.3.7.

The Contractor shall satisfy the Engineer that the plant(s) proposed for use is compatible with the pour sizes shown on the Drawings and that sufficient stand-by capacity, if required by the Engineer, is available.

3.2.3.3 Handling of Materials

i. Cement

Either bagged or bulk cement may be used. No fraction of a bag of cement shall be used in a batch of concrete unless the cement is weighed.

All the bulk cement shall be weighed on a suitable weighing device. The bulk cement weighing hopper shall be properly sealed and vented to prevent the escape of cement dust during the operation. The discharge chute shall not be suspended from the weighing hopper and shall be so arranged that cement will not lodge in it nor leak from it.

ii. Water

Unless the water is to be weighed the water measuring equipment shall include an auxiliary tank from which the measuring tank shall be filled. The measuring tank shall be equipped with a tap and valve to provide for checking then setting, unless other means are provided for readily and accurately determining the amount of water in the tank. The volume of the auxiliary tank shall be at least that of the measuring tank.

Any admixtures whose use has been consented to by the Engineer shall be added to the water prior to the addition of water to the dry batched materials.

iii. Aggregates

Stockpiling of aggregates shall be in accordance with Clause 3.2.2.8. All aggregates produced or handled by hydraulic methods, and washed aggregates, shall be stockpiled or binned for at least 12 hours before being batched. Rail shipment requiring more than 12 hours will be accepted as adequate binning only if the car bodies permit free drainage. Should the aggregates contain a high or non-uniform moisture content, a storage or stockpile period in excess of 12 hours may be required by the Engineer.

iv. Bins and Scales

Where central batching plants are employed the plant shall include bins, weighing hoppers, and scales for the fine aggregate and for each size of coarse aggregate. The shape of the bins shall be such as to ensure that all materials are able to the outlet of the bin and no shovelling is required. If cement is used in bulk, a bin, hopper and, unless otherwise indicated, a scale shall be included. Bins with adequate separate compartments for fine aggregate and for each size of coarse aggregate shall be provided in the batching plant. Where directed by the Engineer suitable screens shall be fitted to the bins.

The Contractor shall furnish acceptable scales or other weighing devices. Weighing hoppers and scales shall be capable of determining the mass of individual materials to within one (1) percent accuracy.

3.2.3.4 Batching of Concrete Remote from the Mixer

Where batches need to be hauled to the mixer, bulk cement shall be transported either in waterproof compartments or between the fine and coarse aggregates. When cement is placed in contact with the moist aggregates, batches will be rejected unless mixed within one and one half (11/2) hours of such contact. Bagged cement may be transported on top of the aggregates.

Batches shall be delivered to the mixer separate and intact. Each batch shall be dumped cleanly into the mixer without loss, and when more than one batch is carried on the truck, shall be dumped without spilling of material from one batch compartment into another.

3.2.3.5 Mix Adjustment for Aggregate Moisture Content

The moisture content of the fine and coarse aggregates shall be determined as frequently as requested by the Engineer either by a moisture meter or by methods consented to by the Engineer. Corresponding corrections shall be made to the quantities of all aggregates as well as to the quantity of water used.

3.2.4 Mixing and Delivery

3.2.4.1 General

Concrete may be mixed at the site of construction at a central point or by a combination of central point and truck mixing. Truck mixing shall be in accordance with the appropriate requirements of AASHTO M 157.

For mixing at the site or at a central point, concrete shall be mixed in a batched mixer of an approved type. No mixer having a rated capacity of less

than a one-bag batch shall be used. The volume of concrete mixed per batch shall not exceed the mixer's nominal capacity as shown on the manufacturer's standard rating plate on the mixer except that an over-load of up to 10 percent above the mixer's nominal capacity may be permitted, provided concrete test data for strength, segregation, and uniform consistency are satisfactory and provided no spillage of concrete takes place. The batch shall be so charged into the drum that a portion of the water shall enter in advance of the cement and aggregates. The flow of water shall be uniform and all water shall be in the drum by the end of the first 15 seconds of the mixing procedure. Mixing time shall be measured from the time all materials, except water, are in the drum. Mixing time shall be not less than 60 seconds for having a capacity greater than 1.50 cubic meters, the mixing time shall be not less than 90 seconds. If timing starts the instant the skip reaches its maximum raised position, 4 seconds shall be added to the specified mixing time. The mixing time ends when the discharge chute opens.

The mixer shall be operated at the drum speed as shown on the manufacturer's name plate on the mixer. Any concrete mixed less than the specified time shall be discarded and disposed of by the Contractor at his own expense.

The timing device on stationary mixers shall be equipped with a bell or other suitable warning device adjusted to give a clearly audible signal each time the lock is released. In case of failure of the timing device, the Contractor will be permitted to continue operations while it is being repaired, provided he furnishes an approved timepiece equipped with minute and second hands. If the timing device is not placed in good working order within 24 hours, further use of the mixer will be prohibited until repairs are made.

3.2.4.2 Retempering of Concrete

Retempering concrete by adding water or by other means will not be permitted. Water shall only be added to bring the slump to the specified value provided that water content does not cause the design value of the water-cement ratio to be exceeded. Concrete that is not within the specified slumps limits at the time of placement shall not be used.

3.2.4.3 Mixing in an Emergency

Remixing of concrete which has become partially hardened will not be permitted. Such shall not be used in the Works.

Where, by reason of delay, it is desired to hold a batch in the mixer, mixing may be continued for a maximum of ten (10) minutes. For longer periods the batch may be held in the mixer and turned over at intervals as directed by the Engineer.

In the case of breakdown of the mechanical mixing equipment the Engineer may give consent to hand mixing, in small quantities (for mass or reinforced concrete only) so as to reach a support or a suitable location for a construction joint. Hand mixing may only be carried out under the supervision of the Engineer or his representative.

Hand mixing will not be permitted for prestressed concrete.

Where mixing by hand is permitted, the following procedure shall be adopted:

- Hand mixing shall be done on a suitable watertight platform of sufficient size to allow the mixing of at least two batches simultaneously.
- The amount of cement used shall be ten (10) percent more than the amount specified for machine mixed concrete of the same class.
- The fine aggregate and cement shall first be mixed until a uniform colour is obtained and then spread on the mixing platform in a thin layer.
- The coarse aggregate, which shall have been previously drenched with water, shall then be spread over the fine aggregate and cement in a thin layer, and the whole mass turned as further water is added with a rose sprinkler.
- After the water is added, the mass shall be turned at least three times, not including shovelling into barrows or forms, until the mixture is uniform in colour and even in appearance.
- Hand mixing of batches shall not exceed 0.2 cubic metres per batch.
- At least two test specimens shall be moulded for 28 days acceptance test from hand mixed concrete. These tests shall be additional to those required in accordance with Clause 3.3.7

3.2.5 Acceptance of Concrete

3.2.5.1 Concrete Control - General

The Contractor will be fully responsible for the supply and delivery of concrete under this Contract.

Concrete shall be produced from a mixing plant which has been consented to by the Engineer for the particular strength grade of required. Where concrete is to be mixed away from the site, it will be supervised by the Engineer or his representative.

The Contractor shall not obtain supplies of concrete from a plant for use in the Works without giving 24 hours notice to the Engineer on each occasion. The Engineer will not accept responsibility for any loss or delay to the Contractor by his failure to provide notice to the Engineer.

Concrete shall not be mixed until consent to do so has been given by the Engineer. Such consent may be withheld or withdrawn for any reason deemed sufficient by the Engineer, including unclean excavation or formwork, unsatisfactory formwork, incorrect reinforcement, inadequate transporting or compacting equipment, insufficient Contractor's labour, inclement weather or conditions which are unsafe.

3.2.5.2 Consistency of Concrete

The concrete to be placed in the work shall be of such consistency that it can be placed, compacted and worked readily into all corners, angles and narrow sections of the forms and around reinforcement without causing segregation of the materials or excess free water to collect on the surface.

The Contractor shall state (when submitting details of the proposed mix design) the slump value proposed for each mix within the limits contained in Clause 3.2.1

The consistency of the concrete shall be determined by a slump test in accordance with AASHTO T 119 (ASTM C 143). The Contractor shall provide at his own cost all equipment and facilities for the taking of the slump tests. The tests shall be made in the presence of the Engineer or his Representative.

Unless otherwise consented to by the Engineer, the slump of the concrete shall not exceed 100 mm for strength grades up to 35 MPa (350 kg/cm^2) and 80 mm for strength grades of 35 MPa and above.

3.3 CONCRETE IN STRUCTURES

3.3.1 Responsibility of the Contractor

The Engineer may request that the Contractor submits, for consent, drawings, Specifications, calculations and other information as shall be necessary to satisfy the Engineer as to the suitability and adequacy of the falsework, scaffolding and formwork that the Contractor intends to use on the works of the Contract.

Consent of the Engineer shall not relieve the Contractor of any of his responsibilities under the Contract.

3.3.2 Formwork

3.3.2.1 Design

Formwork shall be provided to produce hardened concrete to the lines, levels and shapes shown on the Drawings or specified elsewhere. It shall have adequate strength to carry all applied loads, including the pressure of fresh concrete, vibration effects, weight of workmen and equipment, without undue loss of shape. Forms shall be mortar tight and designed to allow removal without risk of damage to the completed structure. Joints in the formwork shall be perpendicular to the main axis of the shape of the concrete, unless otherwise directed or approved by the Engineer.

If required by the Engineer, detailed drawings, design calculations, including design assumptions such as rate of pouring and concrete temperature, description and/or samples of materials proposed for use shall be submitted for the Engineer's consent, before manufacture of the formwork is commenced.

Formwork shall be so constructed and be sufficient to tolerate high frequency vibration and shall be uniform stiffness to avoid causing varying vibration amplitudes over the formwork surfaces during compaction of the concrete.

Design of formwork shall be such that it shall not be necessary to drop concrete freely from a greater height than two (2) metres or to move concrete along the formwork after deposition.

For beams, girders and similar members the design of the formwork shall allow removal of the side forms, without interference with other forms and/or falsework. Removal of all forms shall be possible so that the load is transferred from the forms and falsework to the structure smoothly and gradually.

Provisions shall be made for the accurate location and firm support of fittings, bolts, ducts, anchorages and formers and holes as shown on the

Drawings. Temporary fittings used for the support of the formwork shall be arranged to permit removal without damage to the concrete.

Forms for edges of concrete shall provide chamfers and for re-entrant angles fillets as shown on the Drawings, or if not shown, of 25 mm on each side with equal angles in all cases. Where shown on the Drawings corners shall be formed with fillets or curves.

Where formwork is intended for re-use several times, the design shall allow for the deterioration of the materials in handling.

The use of non-removable formwork will not be permitted unless shown on the Drawings or ordered by the Engineer.

3.3.2.2 Construction

Forms shall be of timber, steel, precast concrete, polystyrene or other approved material. Materials used for formwork shall be sound, clean, free from imperfections and sufficiently uniform so that the specified surface finish can be attained. All timber shall be free from knotholes, loose knots, cracks, splits, warps and other defects which would affect the strength of the formwork or the appearance of the finished concrete surface.

Timber forms for exposed surfaces shall be constructed from plywood or particle board with hardwood or approved softwood studs and wales. Dressed timber forms may be used only with the consent of the Engineer.

The type and quality of material selected for formwork and workmanship used in construction shall be such that the surface specified shall be obtained. (See Clause 3.3.8). Forms shall be constructed in such a manner that stripping shall not result in damage to the concrete.

Formwork for all exposed surfaces shall be made from panels having uniform widths of not less than one metre and uniform lengths of not less than two metres, except where the dimensions of the members of the member formed are less than the specified panel dimensions. Plywood panels shall be placed with the grain of the outer plies perpendicular to the studding or joists, unless otherwise permitted by the Engineer. Where plywood form panels are attached directly to the studding or joints the panel shall be not less than 15 mm thick. Plywood from panels less than 15 mm thick, otherwise conforming to these requirements may be used with a continuous backing of dressed material of 20 mm minimum thickness. All form panels shall be placed in a neat, symmetrical pattern subject to the consent of the Engineer.

Forms for all surfaces which will be completely or permanently hidden below the ground may be constructed from dressed or undressed timber, steel, plywood or particle board.

The use of wires or bolts extended to the surface of the concrete will not be permitted except where shown on the Drawings, or if consented to by the Engineer.

Any embedded ties shall remain embedded and shall terminate not less than twenty five (25) mm back from the formed surfaces. Ties shall be constructed so that the removal of the end fasteners can be accomplished without spalling the concrete faces. All recesses shall be filled in accordance with the requirements of Clause 3.6.3 of this Specification.

Ties embedded in parts of the structure below the water shall have stainless steel tips. Stainless steel sections of the tie rods shall extend not less than

seventy five (75) mm into the concrete from the face of the face recess formed by the inner spacer.

3.3.2.3 Erection of Formwork

Dimensions and position of forms, especially those affecting the construction of subsequent portions of the work, shall be carefully checked after the forms are erected. Forms shall be aligned accurately and the location of all fittings, hole formers, etc. checked prior to placing concrete. Overall accuracy of the formwork shall be to the satisfaction of the Engineer and shall ensure that the requirements of Clause 3.3.9 Tolerances are met.

The interior surface of the forms shall be treated with the lightest practical coating of an approved non-staining release agent before the steel reinforcement or other insertions are placed to ensure non-adhesion of the mortar.

The formwork shall be inspected by the Engineer and the placing of reinforcement in the spaces formed shall not commence until consent is given by the Engineer.

The formwork shall be again inspected by the Engineer before placing of concrete is commenced. Before consent to commence concreting is given, all dirt, chips, hardened concrete or mortar and all foreign matter shall be removed from the forms.

Such consent will not relieve the Contractor of responsibility for any defects in the formwork, reinforcement, embedded components, or the formed concrete surface which may become apparent during or after casting the concrete.

When an inspection is requested by the Contractor, a notice of not less than 24 hours shall be given to the Engineer.

3.3.2.4 Removal of Formwork

All formwork shall remain in place until removal is authorised by the Engineer. The formwork shall be undisturbed until the concrete has adequately hardened and has attained the necessary strength to carry its own weight and construction loads. When required forms shall remain in place to protect the concrete against the effects of low temperature or excessive evaporation. Unless otherwise specified or directed by the Engineer in writing, forms shall not be removed from the concrete until the times specified in Table 3.6 have elapsed. These periods may be extended by the Engineer.

Forms for columns and other load bearing members shall always be stripped to determine whether they are satisfactory before removing falsework from any structural members they support.

In the case of complicated shapes where shrinkage stresses could cause cracking, the Engineer may permit side forms to be loosened at an earlier stage.

In the case of concrete containing special admixtures, stripping times shall be as determined by the Engineer who will take into consideration the age which such concrete would have the same strength as that containing ordinary Portland Cement without additives.

To permit the satisfactory finishing of kerbs, crash barriers, posts etc. forms for such members shall be removed in not less than 12 hours nor more than 48 hours after placing concrete, depending on weather conditions. The

forms for adjacent parts of the structure shall be specially designed to permit this being done without injury to the concrete.

All recesses shall be filled in accordance with the requirements of Clause 3.5.3 of this Specification.

Table 3.6 – Times for Removal of Formwork

Position of Form	For Concrete Mix designed on Use of :	
	Ordinary Portland Cement (moisture curing)	High Early Strength Portland Cement
Sides of beams, columns, wall etc. when the height of each day's pour is:		
• Under 0.6 m	1 day	18 hours
• 0.6 to 3.0 m	2 days	1.5 days
• 3.0 to 6.0 m	3 days	2.5 days
• 6.0 to 9.0 m	5 days	4 days
Sides of Square Piles	12 hours	8 hours
Sides of Octagonal Piles	24 hours	18 hours
Supporting forms and falsework:		
• Under deck slabs of girder bridges	7 days	7 days
• Under simply supported slab spans	10 days	10 days
• Under the stems of simply supported girders and single span arches	21 days	21 days
Supporting forms and falsework under prestressed concrete members	Until 70 percent of the prestressing force is applied to the concrete unless otherwise directed	

3.3.2.5 Precast Deck Formwork

Where shown on the Drawings deck formwork shall comprise precast concrete slabs. The slabs span between the tops of the beams, are completely self-supporting, and are not recoverable. The Contractor shall supply and erect conventional formwork for the deck overhanging he outer beams and where required elsewhere, such as at the end of the spans. Unless otherwise specified or shown on the Drawings, the slabs shall be manufactured by the Contractor.

Before placing slabs, the seating along the top flanges of the beams shall be brushed clean, then cement mortar placed in a thin layer along each seating to improve the bearing of the slabs. The slabs shall be laid before the mortar commences to set, and shall be butted tightly together. After placing slabs and before placing reinforcement, all joints between slabs, and between beams and slabs, shall be filled with mortar. Immediately before concrete in placed in the deck, the whole of the formwork slabs and tops of beams shall be thoroughly wetted and kept wet until covered with concrete. All costs of handling, setting, and stopping for formwork slabs shall be deemed to the included in the schedule item for deck concrete.

Note: The use of precast deck formwork is not applicable to this contract.

3.3.3 Joints

3.3.3.1 Construction Joints

Construction joints shall be located where shown on the Drawings or permitted by the Engineer. Construction joints shall be perpendicular to the principal lines of stress and in general shall be located at points of minimum shear.

At horizontal construction joints, gauge strips 40 mm thick shall be placed inside the forms along all exposed faces to give the joints straight lines. Before placing fresh concrete, the surfaces of construction joints shall be sandblasted or washed and scrubbed with a wire broom, drenched with water until saturated, and kept saturated until the new concrete is placed. Immediately prior to placing new concrete the forms shall be drawn tight against the concrete already in place and the old surface shall be coated thoroughly with a very thin coating of neat cement mortar. Concrete in substructures shall be placed in such a manner that all horizontal construction joints will be truly horizontal and, if possible, in locations such that they will not be exposed to view in the finished structure. Where vertical construction joints are necessary, reinforcing bars shall extend across the joint in such a manner as to make the structure monolithic. Special care shall be taken to avoid construction joints thorough large surfaces which are to be treated architecturally.

Necessary dowels, load-transfer devices, and bonding devices shall be placed as shown on the Drawings or directed by the Engineer.

3.3.3.2 Expansion Joints

Provision for expansion and contraction in concrete structures shall be as shown on the Drawings. Expansion details are designed and dimensioned for installation at a mean temperature of twenty-seven (27) degrees Celsius. Where the ambient temperature is likely to vary by more than five (5) degrees from twenty-seven degrees Celsius the Contractor shall request the Engineer to give a direction regarding any allowance which shall be made in setting the expansion joint.

Joint gaps shall be constructed as shown on the Drawings.

The supply and installation of deck expansion joints in bridge decks shall be in accordance with the technical proposal which shall be provided by the Contractor to the Engineer for his review and approval prior to their procurement and installation.

3.3.3.3 Open Joints

Open joints shall be constructed where shown on the Drawings by insertion and subsequent removal of a wooden strip, metal plate or other approved material. The insertion and removal of the template shall be carried out without causing damage to the concrete. Reinforcement shall not extend across an open joint unless so shown on the Drawings.

3.3.3.4 Filled Joints

The openings for pre-formed, poured or other expansion joints shall be constructed in a similar manner to open joints.

Where shown on the Drawings, joints shall be filled with purpose-made elastic joint filler. The Contractor shall submit samples and technical data of his proposal for joint filler not less than 3 months before its intended use.

Joint filler shall be pre-formed, highly resilient-type sponge or cellular rubber conforming to ASTM D 1056, of 10 mm thickness and of density not less than 30 kg/m³. Joint filler shall be held in place against the completed side of an expansion joint by a waterproof cement or other approved means.

Joint filler shall have, but not be limited to, the following minimum properties:

- It shall exhibit sustained adhesion to concrete under wet conditions and not become brittle after prolonged hot dry conditions
- It shall not rupture as a result of a shear movement of 50 mm
- It shall be non-toxic and non-injurious to concrete.

All joint surfaces to be filled shall be clean, dry and fully cured.

3.3.4 Falsework and Scaffolding

The design, erection and removal of falsework and scaffolding and shall comply with the requirements of Section TS 10 of the Technical Specification.

3.3.5 Placing of Concrete

3.3.5.1 Breaking Back Concrete and Bonding of New Concrete

Where applicable, concrete in the existing structure shall be broken back as shown on the Drawings. Any cracked or damaged concrete remaining after breaking back shall be removed and replaced with new concrete to the satisfaction of the Engineer.

All faces of concrete against which new concrete is to be placed shall be scabbled, brushed clean, and then coated with an approved epoxy resin or other approved bonding agent immediately ahead of the placing of the new concrete. Concrete or bonding agent shall not be placed until the surface against which the concrete is to be placed has been inspected and approved by the Engineer.

3.3.5.2 Chipping Back Surfaces of Existing Concrete Structures and Bonding of New Concrete

Where applicable, existing concrete structures shall be chipped back as shown on the Drawings for a minimum depth of 20 mm in order to expose concrete.

The chipped surfaces of existing concrete against which new concrete is to be placed shall be brushed clean, and wetted with water then coated thoroughly with a very thin coating of neat cement mortar immediately ahead of the placing of the new concrete. Concrete shall not be placed until the surface against which the concrete is to be placed has been inspected and approved by the Engineer.

3.3.5.3 Placing of Concrete

i. General

Concrete shall not be placed until the forms, and any other embedded items have been inspected by the Engineer and he has been given his consent.

The Contractor shall submit a scheme for the order of concreting the cast in-situ sections of the works six (6) weeks prior to placing.

Placing of concrete shall conform to the assumptions made in the design of the formwork.

If consent is given by the Engineer to pour concrete in other than daylight hours, lighting over the area of the pour, mixing plant, conveying equipment etc. shall be as specified in clause 1.6 of the General Specification.

The working surfaces of platforms and conveying equipment shall be cleaned of all foreign material and set concrete immediately prior to commencement of each continuous placing run.

Prior to and during the placing of concrete, the formwork and the space to be occupied by the fresh concrete, and all embedded items including reinforcement shall be maintained in a clean condition, free of water, mud, oil and other deleterious materials.

After mixing, concrete shall be placed without delay. The methods of transport, handling and placing shall be such to prevent the segregation or loss of the ingredients. Dropping the concrete a height more than 2 metres will not be permitted unless thorough approved pipes or chutes. As far as practicable these pipes shall be kept full of concrete during placing, and their lower ends shall be kept close to the surface of the newly placed concrete.

When wheeled vehicles are used for transportation of concrete, a substantial gangway shall be erected above the reinforcement on supports resting on the formwork. The location and type of supports shall be to the consent of the Engineer. Gangways shall be kept back from the working face a distance of 2 or 3 metres.

Excessive quantities of concrete shall not be deposited at any one point and moved or worked along the forms.

Concrete which has developed its initial set, or which is not placed and compacted within 20 minutes after discharge from the mixer shall not be placed in position and shall be removed from the site immediately.

Between the ends of members, or between specified construction joints, concrete shall be placed in one continuous operation such that the face of the fresh concrete is in a plastic state when succeeding concrete is placed against it.

Where required by the Engineer, concrete shall be placed on a spreading platform transport from the mixer. It shall be turned over to ensure a uniform consistency before it is placed. Under no circumstances shall concrete be thrown from shovels.

Concrete shall not be placed at a rate of less than 2 metres per hour vertically without the consent of the Engineer.

ii. Pumping of Concrete

The Contractor shall assume all responsibility and risks involved in the pumping of concrete, and the Employer will not consider any claims for extra costs involved. Should the design of a mix suitable for pumping require cement additional to that specified in Clause 3.2.1 the cost of the additional cements shall be borne by the Contractor. Prior to commencement of placing concrete in the forms, the initial discharge of concrete shall be pumped to waste until a consistent workable mix is discharged, to the satisfaction of the Engineer. Aluminium pipes shall not be used for the delivery of concrete.

3.3.5.4 Placing Under Water

i. General

Concrete, other than sealing concrete, shall be placed under water only with the permission of the Engineer. Concrete shall not be placed in water flowing faster than one metre per second.

When the Contractor proposes to place concrete under water details of the method, equipment and materials proposed to be used shall be submitted to the Engineer for his consent at least six (6) weeks prior to work being commenced.

Unless otherwise consented to by the Engineer, concrete shall only be placed by tremie pipe or bottom dump bucket.

ii. Tremie pipe

Concrete shall be placed through a smooth bore steel tremie tube sufficiently large to permit the free flow of concrete. Joints between sections of the tube shall be threaded, greases and wrapped with an approved tape to provide waterproof connections. Aluminium tubes shall not be used.

The methods, plant an equipment used for concrete placing shall be such that a continuous supply of concrete is available at the top of the tremie tube during the entire process of placing concrete.

The tremie shall be fitted with a valve or other device so that at no time shall concrete in the tube come in contact with water when it is being filled. The means of supporting the tremie shall be such as to permit its being lowered rapidly when necessary to prevent or retard the flow of concrete. The discharge end shall be completely submerged in concrete at all times and the tremie tube shall always be filled to a height to overcome the head of water. The rate of flow in the tremie shall be controlled by raising and lowering the tube and thus varying the external head of concrete at the lower and of the tube.

At no stage during the concreting operation shall the tremie be lifted to permit continuation of discharge unless sufficient concrete is available at the concreting point to enable the tube to be recharged immediately. Concrete shall be supplied to the tremie at a uniform rate to provide a continuous flow with the tremie tube as full concrete as reasonably practicable.

In the event that water enters the tremie tube or the tremie action is lost during casting and if the Engineer considers that as a result thereof a reasonable risk exist that the quality of the concrete will be impaired, the Contractor may be directed to immediately remove all the concrete placed in the current pouring operation.

The cost of removal of the concrete and all associated costs arising from failure of the tremie shall be borne by the Contractor and no extensions of time will be granted.

If most of the concrete has been placed prior to partial or full breakdown of the tremie action the Engineer may permit the previously placed concrete to remain but direct that no further concreting take place. In this case, the Contractor shall carry out any additional sealing which in the opinion of the Engineer is necessary, and dewater and prepare the surface of the previously placed concrete for re-concreting.

iii. Bottom Dump Bucket

Bottom dump buckets shall be of a type that cannot be discharged until it rests on the surface upon which the concrete is to be placed. The bottom

doors when tipped open shall open freely downwards and outwards. The bucket shall be open at the top but the top surface of the concrete shall be protected from the wash of the water and the bucket shall be lowered and withdrawn slowly to avoid backwash. The bucket shall not be raised to such a height that concrete will fall through water and no agitation, tamping or vibration of the concrete will be permitted during the placing.

iv. Pouring Operation

When concrete is placed by tremie dump bucket it shall be placed in one continuous operation keeping the top surfaces as nearly level as possible until it is brought above the water, or to the required height. The work shall be carried out with sufficient speed to prevent any one layer of concrete taking its initial set before the next layer is placed. No tamping or vibration will be allowed. After dewatering the top of the concrete, all laitance and weak concrete shall be removed and the surface shall be scabbled before subsequent placing of concrete.

3.3.5.5 Compacting

During and immediately after placing, the concrete shall be thoroughly compacted by means of vibration as specified hereunder.

Care shall be taken to fill every part of the works, to force the concrete under and around the reinforcement without displacing it, to work coarse aggregate back from the face, and to remove air bubbles and voids.

Vibration shall not be applied directly, or through the reinforcement, to sections or layers of concrete which have hardened to the degree that the concrete ceases to be plastic under vibration.

It shall not be used to make concrete flow in the forms over distances so great as to cause segregation, and vibrators shall not be used to transport concrete in the forms.

Vibration shall be applied at the point of deposit and in the area of freshly deposited concrete. The vibrators shall be inserted and withdrawn from the concrete slowly. The vibration shall be of sufficient duration and intensity to thoroughly compact the concrete, but shall not be continued so as to cause segregation. Vibration shall not at any one point be to the extent that localised areas of grout are formed. Application of vibrators shall be at points uniformly spaced and not further apart than twice the radius over which the vibration is visibly effective.

Workmen employed in compacting concrete shall be competent and experienced in this work. Any workman who is deemed by the Engineer to be unsatisfactory shall be replaced immediately at the request of the Engineer.

i. Internal Vibrators

Internal vibrators shall be of a type and design approved by the Engineer and shall have a minimum frequency of vibration of 7000 revolutions per minute. The intensity of vibration shall be such as to visibly affect a mass of concrete of 25 mm slump over a radius of at least 500 mm.

Table 3.7. gives the basis for the number of internal vibrators required for satisfactory compaction:

Table 3.7 – Number of Internal Vibrators Required

Rate of Placing Concrete	Number of Internal Vibrators[1]
3 cubic metres per hour	2
6 cubic metres per hour	3
9 cubic metres per hour	4
12 cubic metres per hour	5
15 cubic metres per hour	6

Note (1) Excluding standby capacity

ii. External vibrators

Internal vibration shall be supplemented by such external vibration as is necessary to ensure smooth surfaces and dense concrete adjacent to forms. The number and type of external vibrators and their method of use shall be as required by the Engineer. External vibrators shall have a minimum frequency of vibration of 7000 revolution per minute. One additional vibrator for every four working units or part thereof shall be provided, and kept in readiness for immediate use should a breakdown occur.

3.3.5.6 Deck or Slab Concrete

The upper surfaces of the concrete deck slabs shall be carefully screeded to the shape and levels shown on the Drawings.

Vibrating screeds may be used and shall consist of a screed board with one or more vibrating units fixed to it. Fixed screed support for screed boards shall be arranged parallel to the major axis of the deck or slab. Such screed supports shall be at centres not greater than 3 m.

Screed supports shall be set with sufficient camber to ensure that the finished slab levels are as shown on the Drawings or as directed by the Engineer. Screed supports shall be set to provide the specified deck thickness over the tops of the beams where relevant.

Screed supports shall be fabricated from materials and of sizes approved by the Engineer, and shall be rigidly held in position at a spacing such that there will be negligible deflection during screeding and so that the screed supports can be removed from the concrete at the completion of the screeding. Alternative screeding arrangements to those specified may be used subject to the consent of the Engineer.

Concrete shall be placed evenly and spread to a level slightly above the finished deck or slabs levels, compacted by vibrators, and then screeded by means of a vibrating screed board placed on the screed supports and at right angles to the direction of the screed supports. Immediately screeding has been completed the screed supports shall be removed and the surface made good with additional concrete, and trowelled to shape.

Final finishing operations to a concrete slab shall consist of floating, trowelling, and brooming. Any free surface water shall be removed prior to finishing. Additional materials such as cement, stone dust, or sand shall not be used to dry up surface moisture.

As soon as the concrete slab surface assumes a suitable condition, the surface shall be wood floated in order to fill in holes, remove lumps, and smooth off ridges.

After completion of wood floating, the surface shall be steel trowelled by hand or with a power trowel fitted with rotating steel floats. Power trowelling shall be followed by hand trowelling to remove small irregularities and touch up areas in corners, around openings or holes, and close to obstructions.

The whole surface shall then be roughened with a stiff broom to provide bond for the wearing surface, or to provide skid resistance where an asphaltic wearing surface is not to be applied.

Barrows or other conveyances shall not be wheeled directly on the concrete within a period of seven days of casting. If wheeling planks are placed with care on the slab surface, barrows may be permitted on the wheeling planks not less than 12 hours from the casting of the slab.

The finished slab surface shall comply with the requirements of Clause 3.3.9, Tolerances. Deviations from the slab surface greater than those specified above shall be rectified to the satisfaction of the Engineer.

Prices bid for slab concrete shall be based on the thickness and beam hogs as shown on the Drawings. Payment for the actual amount of additional concrete incorporated in slab thickening to offset variations in beam camber from that shown on the Drawings, will be made in accordance with the provisions of the General Conditions of Contract.

3.3.5.7 Concrete Above Deck

In the case of bridges, concrete above deck shall not be placed until the deck formwork or the falsework for the span has been removed.

Concrete above deck for cast-in-place post-tensioned structures shall not be placed until completion of the post-tensioning operation unless specified or consented to by the Engineer.

Forms shall be accurately built to the dimensions shown on the Drawings. All mouldings, panel work and bevel strips shall be straight and true with neatly mitred joints, and all corners in the finished work shall be true, sharp and clean cut.

The forms for cast-in-place members shall be erected to the specified line and grade, and shall be braced to remain in correct position during the placing of the concrete.

The tops of all posts, kerbs and parapets shall be formed by placing an excess of concrete in the forms and removing or striking off such excess with a wooden template moved on guides attached to the forms, forcing the coarse aggregate below the mortar surface. The use of mortar topping will not be permitted.

The finish shall be as specified in Clause 3.3.8.

3.3.5.8 Rubble or Cyclopean Concrete

Rubble or cyclopean concrete shall consist of concrete containing large embedded stones. It shall be used only with the consent of the Engineer in massive piers, gravity abutments, heavy footings and gravity walls. The class of concrete shall be as shown on the Drawings or as directed by the Engineer. The stone for this class of the work shall conform to the requirements of Clause ..

The stone shall be carefully placed-not dropped or cast-so as to avoid injury to the form or to the partially set adjacent concrete. Stratified stone shall be

placed upon its natural bed. All stone shall be washed and saturated with water before placing.

The total volume of the stone shall not be greater than one-third of the total volume of the portion of the work in which it is placed. For wall or piers greater than 600 mm thickness, stone having a maximum size of 250 mm may be used. Each stone shall be surrounded by at least 150 mm of concrete and no stone shall be closer than 300 mm to any top surface nor any closer than 150 mm to any coping.

Note: Rubble or cyclopean concrete is not applicable to this contract.

3.3.6 Curing

Subject to the consent of the Engineer, curing shall be carried out using one or both of the following methods.

3.3.6.1 Normal Curing

i. General

Exposed concrete surfaces shall be cured by covering with an approved material immediately after finishing and the surface small be kept moist. Alternatively, exposed surfaces may be cured by flooding or continuous sprinkling subjects to the consent of the Engineer.

Curing shall continue for a period of not less than seven days after placing the concrete.

Within 15 minutes if the completion of the finishing of any section of deck or slab, the concrete surface shall be protected by suitable means from the effects of sun and wind.

Freshly finished concrete surfaces shall be effectively protected from rain or damage from other sources until hard set has occurred.

ii. Use of Curing Compounds

Moist curing as specified above shall generally be used. The use of curing compounds will not be permitted on exposed surfaces which require class 2 or class 3 surface finishes.

Curing compounds shall be in accordance with AASHTO M 148 (ASTM C 309) "Standard Specifications for Liquid Membrane Forming Compounds for Curing Concrete" and shall only be used with the consent of the Engineer. Full details of curing compounds shall be submitted to the Engineer prior to their use, including the time and rate of application and documented evidence of the effectiveness of the compound as a curing agent. Such compounds shall be pigmented sufficiently to allow visual inspection to ensure full application on the surface to be coated and the pigment shall not be visible after a period of 14 days after application. Curing compounds shall not have a deleterious effect on the concrete. Compounds shall not darken or yellow appreciably, and no compound shall be used which will stain the surface of the concrete.

Curing compounds shall be applied in accordance with the manufacturer's instructions. Application of curing compound shall commence after the final set has taken place and just as the surface film of water disappears. If the concrete surface is dry, it shall be thoroughly wetted with water and the surface film allowed to just disappear prior to application of the curing compound. Any damage caused to the applied coating shall be immediately

repaired by the Contractor. If coatings are being repeatedly damaged the Engineer may direct that moist curing be resumed.

Curing compounds shall not be applied to construction joints unless the joint id to be scabbled or sandblasted at a later date.

Curing compounds shall not be applied to surfaces which are to be subsequently coated unless provision is made for removal of the compound from these surfaces prior to the application of the coating. Curing compounds to be used on bridge decks which are to be covered by a bitumen seal or asphalt shall be of a type which will not significantly reduce the adhesion of the seal or asphalt.

3.3.6.2 Steam Curing

The plant, and equipment, method of control, and the proposed curing cycle for any steam curing proposed by the Contractor shall be subject to the consent of the Engineer. After the initial maturity period, the concrete shall be cured in an atmosphere saturated with water vapour at a pressure not exceeding atmospheric pressure.

3.3.7 Quality of Concrete

3.3.7.1 Strength

The classes or strength grades of concrete to be used in the works shall be as shown on the Drawings. Test specimen moulds, of a type shown on the Drawings, shall be provided by the Contractor for all tests required to be performed by the Contractor or for independent testing by the Employer pursuant to clause 1.6.2 of the General Specification.

3.3.7.2 Sampling of Concrete

Test specimens shall be made and cured in accordance with AASHTO T 23 (ASTM C 31) "Standard Methods of Making and Storing Specimens of concrete in the Field". Eight test specimens shall be made from each sample of concrete and there shall be not less than 8 specimens made for every 40 cubic metres of concrete or fraction thereof placed during one day's run for every concrete pay item shown in the Bill of Quantities . Where the rate of concrete placement for any single structure exceeds 100 m^3/day, the number of specimens may be reduced from 8 to 2 per 40 cubic metres at the sole discretion of the Engineer.

Additional specimens, as directed by the Engineer or detailed in Section TS 7 of this Specification, shall be taken for the assessment of the strength where early stripping of forms or the early application of prestress is proposed.

The Contractor shall provide the necessary curing facilities and shall cure the test specimens on site in accordance with AASHTO T 23 until they are tested by the Contractor in accordance with his obligation for testing under the contract or delivered to the laboratory for independent testing pursuant to clause 1.6.2 of the General Specification.

As soon as practicable after the specimens are made they shall be placed in approved moisture proof containers until testing is to be carried out.

3.3.7.3 Sampling of Mortar and Grout

If required by the Engineer, test specimens shall be made for the purpose of determining the properties of mortar or grout. The specimens shall be made in accordance with Clause 3.3.7.2 above, except that the method of moulding shall be as directed by the Engineer.

Test specimens for shrinkage tests shall be in accordance with AASHTO T 23.

3.3.7.4 Testing

The concrete specimens will be tested in accordance with AASHTO T 22 (ASTM C 39).

Four of the above eight specimens shall be tested at 7 days for information and the other four at 28 days for acceptance.

A strength test shall be defined as the average of the compressive strengths of two specimens made from the same composite sample of concrete and tested at 28 days.

Where samples are taken from concrete which will be prestressed, four specimens will be tested to assess the concrete strength prior to stressing and four specimens will be tested at 28 days.

Should the average strength of the strength test above be less than the specified strength, application of prestress or removal of forms (as appropriate) shall not take place. Alternatively the Engineer may specify an age at which in his opinion the concrete will have reached the required strength to permit application of prestress or removal the forms. If the concrete was steam cured, the Engineer may request additional in accordance with the requirements of Clause TS 3.3.6.1.

The requirements for each class of concrete are as shown in Table 3.8.

Table 3.8- Compressive Strength Requirements

Classes of Concrete	Specified Compressive Strength			
	7 Days		28 Days	
	(MPa)	(kg/cm^2)	(MPa)	(kg/cm^2)
K125	9.0	90	12.5	125
K175	13.0	130	17.5	175
K225	17.0	170	22.5	225
K350	26.0	260	35.0	350
K400	30.0	300	40.0	400
K500	38.0	380	50.0	500

Irrespective of the quantity, every day's production of concrete shall be tested both for strength and for slump and every structure and every component of every structure shall likewise be so tested for strength and slump.

The Engineer may order an increase in the number of tests to be made or make other tests as he may deem necessary to ensure that the concrete is of the specified quality.

The concrete test specimens will be tested by the Contractor and witnessed by the Engineer at a laboratory approved by the Engineer.

The cost of testing the specimens will be borne by the Contractor.

Concrete test specimens shall be provided by the Contractor further to his obligation to allow independent testing by the Employer in accordance with clause 1.6.2. of the General Specification.

3.3.7.5 Acceptance of Concrete

The strength requirements of concrete in this Specification will be satisfied when, for any given sample, the strength requirements of Clause 3.2.1.4 are met and, in addition, no strength test (as defined in Clause 3.3.7.4 above) is less than the specified Characteristic Strength at 28 days by more than 3.5 MPa (35 kg/cm^2).

The Contractor may carry out tests on specimens made by him or his representatives in addition to the number specified above, to determinate the time at which the various strength requirements will be met. However, acceptance or rejection of the specified strength requirements will be based on test carried out under the supervision of the Engineer.

3.3.7.6 Rejection of Concrete

Should any sample fail to satisfy the strength requirements of consent as detailed in Clause 3.3.7.5 above, the Engineer may reject the whole or part of the concrete represented by the sample.

In the case of doubtful results the Engineer may proceed to check the compressive strengths by means of crushing tests performed on test specimens taken with a rotary core borer at points indicated by the Engineer on structures already constructed. If such tests do not comply with the requirements the Engineer may reject whole or part of the concrete represented by the those tests. These tests shall comply with the requirements of ASTM C 42.

If the Contractor disputes any of the above test results the Engineer may require the Contractor to have confirmatory tests made at the Contractor's expense. Such tests shall consist, according to the Engineer's instructions, of crushing tests as described in the paragraph above or non- destructive tests using the sclerometer (refer to ASTM C 805).

Each non-destructive test shall be performed as follows:

- Around the point selected by the Engineer, an area not larger than 0.1 square metres shall be fixed, on which ten (10) blows with the sclerometer shall be made and the values of index read each time shall be recorded;
- The arithmetic mean of such values shall be determined;
- Values which differ from the arithmetic mean by more than fifteen hundredths (15/100) of the total range of the sclerometer scale shall be discarded;
- From the values not discarded the arithmetic mean shall be recalculated and by reference to the calibration table of the sclerometer scale will give the compressive strength of the concrete;

Generally, for each of type of sclerometer the calibration table supplied by the manufacturer will be used. Nevertheless the Engineer will have the right, as desired, to perform the calibration of the sclerometer directly on specimens which will afterwards be subjected to crushing tests by simple compression.

Rejected concrete shall be removed by the Engineer, at his own expense, in accordance with the provisions of the General Conditions of Contract.

The records of all tests shall be kept by the Engineer but results shall be available at all times to the Contractor. The Contractor shall be responsible for making such adjustments as may be necessary to produce specification concrete and the test results shall indicate whether or not the concrete is satisfactory.

3.3.8 Surface Finish

3.3.8.1 General

For any particular class of concrete surface finish, the method of construction and the materials used in the concrete and fomwork shall remain constant and shall be such as to meet the requirements of this Specification. Any formwork which in the opinion of the Engineer will not impart a surface finish in accordance with the requirements of this Specification will be rejected.

The standard of surface finish is dependent on the quality of formwork, the compaction of the concrete, and the manner in which the formwork is removed. The higher the standard of surface finish required the greater care will be required to be given to these factors.
The following surface finishes are specified :

Unformed Surface Finish
Class 1 Surface Finish (Unexposed Formed Surface Finish)
Class 2 Surface Finish (Ordinary Formed Surface Finish)
Class 3 Surface Finish (Rubbed Formed Surface Finish)

All formed concrete shall receive at least a Class 1 surface finish. Unless otherwise consented to by the Engineer the surface of the concrete shall be finished immediately after the removal of forms.

Except where other surface finishes are shown on the Drawings or ordered by the Engineer, surface finishes Class 1, Class 2 and Class 3 shall be used as follows:
Substructures

The Back of abutments, culverts, concrete retaining walls and wingwalls shall receive Class 1 surface finish.

All exposed surfaces of abutments, wingwalls, concrete retaining walls,pumping station structure, gate structures, and piers from 300 mm below ground level shall receive Class 2 surface finish, except that in cellular structures the faces of wingwalls and ends piers or wall only shall receive Class 2 surface finish. Upper surfaces of concrete bearing pedestals shall receive Class 2 surface finish.

Bridge Decks and Beams

The underside of deck between beams and vertical faces of beams other than the outer face of outer beams shall receive Class 1 surface finish. The outer faces and undersides of the beams, the edges and the underside of the cantilevered deck slab, the interior and exterior faces of kerbs and the upper surfaces of the kerbs shall receive Class 2 surface finish.

Exposed Visible Surfaces

All surfaces above the tops of kerbs shall receive Class 3 surface finish. End posts shall receive Class 3 surface finish. Precast parapet units and associated cast-in-place concrete shall receive Class 3 surface finish.

Precast Concrete

Precast parapet units shall be given a Class 3 surface finish.

Other precast units shall receive Class 2 surface finish.

All precast units shall receive this finish within forty eight (48) hours of removal of forms.

3.3.8.2 Rejection of Surface Finishes

Any concrete surface that does not comply with the requirements of this Specification shall be subject to one of the following alternatives, at the sole discretion of the Engineer.

1) Rejection of the concrete, in which case the concrete shall be demolished and replaced.

2) Approval of the concrete cast will be withheld subject to remedial measures being carried out the satisfaction of the Engineer.

The cost of any demolition or restoration work to be undertaken shall be borne by the Contractor.

3.3.8.3 Unformed Surface Finishes

i. Surfaces other than Wearing Surfaces

Unformed surfaces shall be compacted and tamped so as to flush mortar to the surface, screeded off and finally dressed with a wooden float to an even surface. Care shall be taken to drain or otherwise remove promptly any water which comes to the surface. A capping of mortar will not be permitted.

All future contact surfaces in composite construction shall be left rough, with the coarse aggregate at the surface firmly embedded but not forced below the surface.

ii. Wearing Surfaces

Where a concrete is shown on the Drawings (for example for the deck of a bridge), the concrete shall be thoroughly compacted and the surface screeded off by a suitable vibrating screed. Immediately following compaction and screeding the concrete shall be finished and shall be finally dressed with a wooden template or float or by other suitable means. The departures from grade shall not exceed 5 mm in any 3 metre length.

Where an asphaltic deck wearing surface is specified, the surface of the concrete, after being compacted, screeded and corrected, shall be dressed with a wooden float to close drying shrinkage cracks. Unless otherwise shown on the Drawings, all deck slabs shall have a broomed finish applied to the top surface while the concrete is still plastic. Brooming shall be done in a direction transverse to the longitudinal axis of the slab.

3.3.8.4 Class 1 Surface Finish

For a Class 1 surface finish no defects which structurally affect the concrete or reduce the cover to the steel reinforcement will be permitted. As soon as the formwork is removed, rough or porous areas shall be filled with a suitable stiff cement mortar, having the same proportions of cement and fine aggregate as used in the concrete, and shall be brought to an even surface with a wooden float. Bolts, wires and other appliances passing through the

concrete to hold the formwork shall be cut off set back a minimum of 25 mm from the surface of the concrete, and the ends covered with a suitable mortar. If concrete spacer blocks are used they shall be manufactured with concrete of the same mixture as the parent concrete in the structure.

3.3.8.5 Class 2 Surface Finish

Surfaces to receive a Class 2 finish shall have the treatment specified above for Class 1 finishes together with the additional requirements below.

A Class 2 surface finish shall achieve a concrete surface of invariable colour and free from any major surface defects. The design of the formwork shall be such as to give a deflection under the loads imposed on it of not more than 5 mm between studs of frame supports. The formwork shall be assembled by skilled tradesmen from materials which are suitable for this standard of formwork. The formwork shall be constructed so as to prevent water run off carrying stains on to previously cats concrete surfaces. The finished concrete surfaces shall be protected from mortar slurry, physical damage, spillage and water borne staining. Timber in contact with a concrete surface shall be softwood and any steel shall be protected to prevent rust staining of the concrete surface. No defect which structurally affects the concrete or reduces the cover to the steel reinforcement or other embedded components will be permitted.

All mortar fins shall be tooled away to expose a surface of dense sound concrete.

Excessive colour variations in the finished concrete surfaces shall be remedied at the Contractor's expense.

Embedded spacers and reinforcement supports which project to the surface of the concrete shall generally match the colour of the concrete and be of such design that only a minimal area is exposed after stripping.

Details of the proposed spacers and supports shall be submitted to the Engineer for his consent.

The use of concrete spacer blocks will not be permitted.

If any of the surfaces for which Class 2 Surface Finish is specified do not exhibit the required finish off the forms they shall be treated as specified for Class 3 finish below.

3.3.8.6 Class 3 Surface Finish

Surfaces to receive a Class 3 finish shall have the treatment specified above for Class 2 finishes together with the additional requirements below.

A Class 3 surface finish shall achieve a concrete surface of uniform colour and texture and free from surface defects. The design of the formwork shall be such as to give a deflection under the loads imposed on it of not more than the following:

- 1.5 mm between adjacent framing members
- 3.0 mm over the vertical face for the full depth of a panel, or height of a lift, whichever is the lesser.
- 3.0 mm over a 3 metre length horizontally.

Formwork shall be assembled by skilled tradesmen from materials which are suitable for this standard of formwork. Hardwood shall not be used in formwork construction and any steel shall be protected to prevent rust

staining of the concrete surface. The formwork shall be constructed so as to prevent water run off carrying stains on to previously cast concrete surfaces. The finished concrete surface shall be protected from mortar slurry, physical damage, spillage and water borne staining. No defect which structurally affects the concrete or reduces the cover to the steel reinforcement or other embedded components will be permitted. If the concrete surface finish is not of uniform colour and texture remedial measures shall be taken by the Contractor to produce the required surface finish at his own expense and to the satisfaction of the Engineer.

After the forms are removed mortar fins and irregular shall be removed and the surface shall be thoroughly wetted. It shall then be rubbed with No. 16 carborundum stone or similar abrasive until all form marks are removed and the surface is uniform in texture and the arrises are true. The paste formed in the process shall be uniformly distributed over the surface while it is still wet and allowed to set. It shall then be rubbed off with dry hessian or canvas.

Sandblasting shall only be permitted where environmentally acceptable.

3.3.9 Tolerances

The tolerances listed in Table 3.9 will be the basis for acceptance of the work. Work outside the specified tolerances may be rejected by the Engineer.

Table 3.9 Tolerances for Concrete Construction

COMPONENT	ITEM	TOLERANCE
Precast Concrete Piles (including Sheet Piles)	Variation in cross sectional dimensions	± 5 mm
	Variation in length	± 25 mm
	Squareness of head to longitudinal axis	± 5 mm
	Variation of the point to centre of the pile	± 5 mm
	Surface irregularities measured with 3 m straight edge	5 mm
	Bow for the length in mm (Variation from the straight)	$\frac{\text{Pile length}}{1000}$
Footings and Piles Caps	Variation in dimensions	+ 50 to – 10 mm
	Misplacement from the specified position	15 mm
	Surface irregularities measured with a 3 m straight edge	5 mm
	Variation of reduced levels at the tops of footings or pile caps	± 25 mm
Post Tensioned Prestressed Concrete Beams	Variation in top and bottom flange thickness	- 5 mm to + 10 mm
	Variation in wall thickness	- 5 mm to + 10 mm
	Variation in overall depth or width	± 5 mm
	Variation in overall length and length between bearings shall not exceed ± 10 mm or ± 0.1 percent of the span length whichever is the lesser	
	Variation in hog from specified profile shall not exceed 0.1 percent of the span length. Sag will not be permitted unless specified. The hog of beams in any one span shall not vary from the other by more than 15 mm.	
	Bow shall not exceed 10 mm or 0.1 percent of the span length whichever is greater.	
	Permissible surface irregularities when measured with a 3 m straight edge or template	5 mm
In situ Beams, Slabs, Columns, Piers, Walls, Railings, Kerbs and other similar parts	Variation in dimensions	± 5 mm
	Misplacement from the specified position	5 mm
	Variation of reduced levels of the tops of columns, piers, wall beams or similar parts.	± 5 mm
	Variation of reduced levels of bearing areas	± 5 mm
	Variation from plumb over full height of columns	± 5 mm

3.3.10 Waterstops

3.3.10.1 General

Waterstop shall be provided where concrete structures require water-tightness- at joints as shown on the Drawings or as directed by the Engineer. The width of the waterstop shall be within a tolerance of 10 mm of the nominal width exclusive of the nailing strips.

3.3.10.2 Material

The waterstop shall be extruded from an elastomeric plastic compound, the basic resin of which shall be polyvinyl chloride (PVC). The compound shall contain any extruded additional resins, plasticisers, or other materials needed to ensure that, when the material is compounded, it will have the physical characteristics specified herein:

Physical Characteristics		Method of Test
Tensile Strength, min	140 kgf/cm²	ASTM D 412
Ultimate Elongation, min	300%	ASTM D 412
Hardness, Durometer (Type-A)	65 to 80	ASTM D 2240
Specific Gravity	1.40 ± 0.2	
Water Absorption, max	0.15%	
Tensile Strength after Accelerated Extraction Test, min	110 kgf / cm²	
Ultimate Elongation after Accelerated Extraction Test, min	240%	
Changes in Weight Effect of Alkali Test	± 5%	

The manufacturer's certification of conformity to the specified requirements shall be submitted to the Engineer for approval.

3.3.10.3 Fabrication

a) The shapes and dimensions of PVC waterstops shall be as shown on the Drawings or as approved by the Engineer.

b) Extruded waterstop shall be dense, homogeneous, and free form holes, scratches and other imperfections. The cross-section of PVC waterstop shall be uniform along its length and shall be transversely symmetrical so that the thickness at any given distance from either edge of the waterstop shall be uniform.

3.3.10.4 Splices

a) Splices in waterstops or at the intersection of runs of the PVC waterstop shall be made with fusion-welded butt splices in accordance with the manufacturer's instruction. All splices shall be neat with the ends of the joined surfaces in alignment and in good contract. The continuity of the characteristics patterns of the cross-sections of the waterstop shall be maintained across the splice. All intersection splices shall be prefabricated at the manufacturer's factory.

b) The number of splices in the waterstop shall be kept to a minimum and all splices shall be approved by the Engineer. The equipment used for making splices and the splicing method shall also be as approved. The equipment used for making field joints shall be a temperature controlled apparatus furnished by the Contractor.

c) The Contractor shall make the splices in such a manner as to ensure that the splices have a tensile strength not less than 80 percent of that of the unspliced material. The Contractor shall undertake testing to confirm the strength of field splices. The splice shall be watertight, free of air bubbles and the rib and centre bulb, where applicable, shall match up exactly and be continuous.

3.3.10.5 Installation

a) To eliminate faulty installation that may result in joint leakage, particular care shall be taken to see that the waterstops are correctly positioned during installation. Adequate provision shall be made to support the waterstops during the progress of work and to ensure the proper embedment in concrete. The method of securing the waterstops will be to the approval of the Engineer. The symmetrical halves of the waterstops shall be embedded in the concrete on each side of the joints. Waterstop shall be thoroughly cleaned of foreign material before concrete is placed.

b) Care shall be exercised in placing and vibrating the concrete about the waterstop to ensure complete filling of the concrete under and about the waterstop and to obtain a continuous bond between the concrete and the waterstop at all points around the perimeter of the waterstop.

c) Suitable guards shall be provided to protect exposed projecting edges and ends of partially embedded waterstop from mechanical damage at all times. The\\ PVC waterstop which will remain exposed for more than 10 days shall be covered or shaded to protect it from the action of temperature and ultraviolet rays.

d) The Contractor shall replace or repair any punctured or damage waterstop.

3.3.11 Miscellaneous

3.3.11.1 Soffits

The soffits of beams and deck edges shall be continuous curves or straight lines as shown on the Drawings. All visible irregularities shall be made good to the satisfaction of the Engineer.

3.3.11.2 Anchor Bolts

All necessary anchor bolts as shown in the Drawings shall be set either before the concrete is placed, or in the concrete as it is being placed, or in holes formed while the concrete is being placed, or in holes drilled after the concrete has set.

If set in the concrete as it is being placed, a bolt shall be placed in a section of standard black pipe, at least 50 mm larger in diameter than the bolt, and shall be anchored by passing through a heavy steel washer at the bottom of the pipe. Holes may be formed by inserting in the fresh concrete oiled wooden plugs, metal pipe sleeves, or other approved devices, and withdrawing them after the concrete has partially set. Holes so formed shall be at least 100 mm in diameter. If drilled, holes shall be at least 25 mm larger in diameter than the bolts used.

Bolts shall be set to be at the levels as shown on the Drawings and deviation from line and level shall not exceed 5 mm. The bolts shall be fixed with grout completely filling holes. The grout shall consist of one part Portland cement to one part fine-grained sand.

Where a group of bolts is installed for anchorage of a fence post or similar, the bolt group shall be installed prior to the placing of concrete. The concrete over the support base plate area shall be scabbled to remove all laitance and loose or porous material and left in a roughened state.

3.3.11.3 Bridge Bearings

Bridge bearings shall be provided and installed in accordance with Section TS 11 of this specification.

3.3.11.4 Pipes, Conduits and Ducts

Pipes, conduits, and ducts that are to be encased in concrete shall be installed by the Contractor before the concrete is placed. Unless otherwise indicated, pipes embedded in concrete shall be standard, lightweight, non-corrosive pipes. Pipes shall be held or braced rigidly during concrete placement in order to prevent their displacement.

3.3.11.5 Block-outs

Block-outs to allow for the subsequent installation of metal components (e.g. gate guide frames) shall be formed as shown on the Drawings and to the tolerances shown in table 3.9.

Where block-outs are formed, the concrete surfaces shall be chipped, roughened and cleaned and kept moist for at least 4 hours. After such surfaces have been inspected and approved by the Engineer, concrete type C-2 as specified in table 3.1 shall be placed. Care shall be taken to ensure that the concrete is tightly bonded to the previously-placed concrete and the complete adhesion between the concrete and all metalwork or other items in the block-out is obtained.

3.4 STEEL REINFORCEMENT

3.4.1 Scope

This clause covers the supply, handling and placing of steel reinforcement for concrete.

3.4.2 Materials

Unless shown otherwise on the Drawings, reinforcement shall consist of deformed steel reinforcing bars, of a strength grade as shown on the Drawings, complying with the requirements of AASHTO M 31M (ASTM A 615).

Where the use of other reinforcement is shown on the Drawings, such reinforcement shall comply with the requirements of the appropriate following standards:

- AASHTO M 225 (ASTM A 496) Deformed Steel Wire for Concrete Reinforcement
- AASHTO M 32 (ASTM A 82) Cold Drawn Steel Wire for Concrete Reinforcement
- AASHTO M 55 (ASTM A 185) Welded Steel Wire Fabric for Concrete Reinforcement

Steel reinforcement shall be supplied free from loose millscale, mortar, loose or thick rust, or any other coating.

3.4.3 Order Lists

Before ordering material, all order lists and bending diagrams shall be furnished by the Contractor for the approval of the Engineer, and no material shall be ordered until such lists and bending diagrams have been approved. Approval of order lists will in no way relieve the Contractor of his responsibility for ascertaining accuracy of such lists and diagrams. Revision of material furnished in accordance with such lists and diagrams to meet compliance with the design drawings shall be at the expense of the Contractor.

3.4.4 Protection of Materials

Reinforcing steel shall be protected at all times from damage and shall be stored on blocks to prevent mud caking. Prior to placing concrete, reinforcing steel which is to be embedded shall be free from heavy rust, dirt, mud, loose scale, paint, oil, or any other foreign substance.

3.4.5 Bending

Unless otherwise permitted, all reinforcing bars requiring bending shall be bent cold and shall be bent in accordance with American Concrete Institute procedures unless otherwise detailed. All hooks and bends shall be in accordance with P.B.I 1971 N.I. 2 (Indonesian Reinforced Concrete Code). Bars partially embedded in concrete shall not be bent except as shown on the drawings or otherwise permitted. Qualified labour shall be employed for cutting and bending, and proper appliances shall be provided for such work. Should the Engineer consent to the application of heat for field bending reinforcing bars, precautions shall be taken to assure the physical properties of the steel will not be materially altered.

3.4.6 Placing and Fastening

All reinforcing steel shall be accurately placed and during the placing of concrete, firmly held by approved supports in the position shown on the Drawings. Reinforcing bars shall be securely fastened together. Reinforcement placed in any member shall be inspected and approved before any concrete is placed.

3.4.7 Splicing

All reinforcement shall be furnished in the full lengths indicated on the Drawings. Splicing of bars, except where shown on the Drawings, will not be permitted without the written consent of the Engineer and then only welded spliced may be permitted. Splices shall be staggered as far as possible.

In the lapped splices, unless otherwise shown on the Drawings, bars shall be lapped 40 diameters to make the splice. Welding of reinforcing steel shall be done only if detailed on the drawings or if authorised by the Engineer in writing. In such cases, the Contractor shall submit to the Engineer for his approval a welding procedure and a list of welders to perform the welding, including their qualifications and details of welder qualification testing to be carried out.

3.4.8 Substitution

Substitution of different size bars will be permitted only upon the specific authorisation of the Engineer. If steel reinforcement is substituted, it shall be of a size equivalent to the design size or larger.

3.5 DEFECTIVE CONCRETE

3.5.1 General

Concrete which is not placed and completed in accordance with this Specification, or does not meet the requirements of this Specification in regards to surface finishes, or which is, in the opinion of the Engineer, defective, shall be removed within the limits assigned by the Engineer, and replaced in accordance with the requirements of Section TS 9, Concrete Repairs of this Specification except as modified below.

No repair to concrete shall be carried out without the consent of the Engineer. All repairs shall be performed by skilled workmen and shall be carried out within 24 hours of the removal of the forms and/or the defect becoming visible.

3.5.2 Materials for the Repair of Defective Concrete

Materials used shall be the same as those used in the parent concrete.

For repairs to Class 2 and Class 3 finishes the proportions of materials shall be determined by experiment to provide a matching colour at 28 days. White cement shall be substituted for a portion of the grey cement as required.

Cement mortar shall consist of one part cement by volume and not more that three parts of fine aggregate by volume and an appropriate quantity of water.

Dry pack shall be composed of a mix of one part of cement by volume to two and one half parts by volume of sand that will pass a 1.18 millimetre sieve, together with just enough water to produce a mortar which will just stick together when moulded into a ball by slight pressure of the hands and not exude water but will leave the hands damp.

Concrete shall have the same strength as the parent material.

3.5.3 Repair of Defective Concrete

All repairs shall be bonded tightly to the parent material, be sound and free from shrinkage cracks and drummy areas after curing and drying and have

the surface finished smoothly and flush with the adjoining surfaces. Repairs to Class 2 and Class 3 finishes where permitted shall be carried out in accordance with the Engineer's directions. The area around the defective concrete shall be marked with saw cuts twenty (20) mm deep, cut on straight lines. Defective concrete shall be excavated to sound concrete to the satisfaction of the Engineer. The excavated area shall be primed with an suitable epoxy adhesive in accordance with the manufacturer's recommendation, and built up with dry-pack, cement mortar or concrete to bring the surface to the tolerances as set out in Clause 3.3.9. Bulges and abrupt irregularities shall be reduced by bush hammering and grinding until the surface is within the required tolerances. The treatment of this and adjoining areas shall be subject to the consent of the Engineer. Where dressing is required, all fins shall be removed and all blowholes and honeycombing shall be filled using cement mortar. The area shall be rubbed down with a cement mortar using only the portion of sand passing the 600 micron sieve and a cement ratio the same as the parent mix but with just sufficient water for workability. The excess material shall be rubbed off within hessian 24 hours later.

Drypack shall be used for filling narrow slots cut for the repair of cracks, for grouting holes and for filling tie rod fastener recesses. Drypack shall not be used for filling behind reinforcement.

Cement mortar filling placed under impact (shotcrete or similar) may be used for the repair of areas which are too wide for drypack, yet too shallow for concrete filling and no deeper than the inner face of the reinforcement nearest the surface.

Concrete filling shall be used for holes greater in area than 0.1 square metres or deeper than 100 mm, and for holes which are greater in area than 0.5 square metres and which extend beyond reinforcement.

Where required cracks shall be sealed and or injected with epoxy resin in accordance with the requirements of Sections TS 9 and TS12 of this Specification.

Any material spilled on or stains to adjacent areas of consent shall be cleaned to the satisfaction of the Engineer.

3.6 MEASUREMENT AND PAYMENT

3.6.1 Concrete

This clause refers to concrete of the various classes, as described in Section TS 3 of this Technical Specification.

Measurement for payment of concrete will be made in cubic metres (m3) in accordance with the dimensions shown on the Drawings or as directed and accepted by the Engineer but the measurement shall not include any concrete used for the construction of temporary work. No deduction will made for the volume occupied by pipes less than 200 mm in diameter nor for reinforcing steel, anchors, conduits, weep holes or piling except that deductions will be made for the volume of structural steel, encased in concrete. The measurement shall not include any concrete used in the construction of cofferdams or falsework, or the volume of forms or falsework. Requirements for any increased cement content, admixtures, or concrete finishing will not be measured separately.

Payment will be made at the rates entered in the Bill of Quantities and shall include the entire cost of completing the work including materials, labour,

equipment, transportation, handling and storage of cement, aggregate, and admixtures (if any),mixing, placing, finishing and curing concrete, construction of joints, formwork, falsework and scaffolding and any other associated costs.

Categories of work to be paid under this clause are as follows:

Description	Unit of Measurement
Concrete, Type B including Formwork	m^3
Concrete, Type C1 including Formwork	m^3
Concrete, Type C1 including Formwork and Falsework	m^3
Concrete, Type C1 including Formwork, Scaffolding and Falsework	m^3
Secondary Concrete, Type C2	m^3
Concrete, Type E including Formwork	m^3

3.6.2 Steel Reinforcement

This clause refers to steel reinforcement, as described in Section TS 3 of this Technical Specification.

Measurement shall be made in kilograms of the masses of steel reinforcement placed in accordance with the Drawings and complying with the requirements of Section TS 3 of the technical specification. The mass so determined shall be based on the mass per metre as tabulated below. The lengths to be used in calculating the mass for the purpose of payment shall be as shown on the Drawings or ordered in writing by the Engineer.

No measurement or payment will be made for splices added by the Contractor for his convenience nor for splices not shown on the Drawings and consented to by the Engineer.

Mass per Metre of Bars for Measurement			
Bar Code	Mass per Metre (kg/m)	Bar Code	Mass per Metre (kg/m)
D10	0.617	D19	2.230
D12	0.888	D22	2.980
D13	1.040	D25	3.850
D14	1.210	D29	5.190
D16	1.580	D32	6.310
D18	2.000	D36	7.990

Payment will be made at the rates entered in the priced Bill of Quantities and shall include the entire cost of completing the work including materials, labour, equipment, transportation, handling and storage of reinforcement, fabrication, bending, assembling and welding of reinforcement, clips and ties and the like for positioning and fastening reinforcing bars and any other associated costs.

Categories of work to be paid under this clause are as follows:

Description	Unit of Measurement
Deformed Reinforcing Bars	kg
Dowel Bar. Dia. 19mm, 1.0m long (round bar and PVC pipe)	kg

3.6.3 Joint Filler

This clause refers to joint filler, as described in clause 3.3.3.4 of this Technical Specification.

Measurement will be made of the area of joint filler, 10 mm thick, which has been installed and accepted. The area measured will be the gross area. No deduction shall be made for waste.

Payment will be made at the rate entered in the priced Bill of Quantities which shall include full payment for providing all labour, materials, tools, equipment and any other works incidental to the completion joint filler.

Categories of work to be paid under this clause are as follows:

Description	Unit of Measurement
Joint Filler, 10mm thick (Elastic Material)	m^2

3.6.4 Waterstops

This clause refers to waterstops as described in clause 3.3.10 of this Technical Specification

Measurement will be made of the length of water stop supplied, installed and accepted.

Payment will be made at the rate entered in the priced Bill of Quantities which shall include full payment for all labour, materials, tools, equipment and incidentals for furnishing, testing, cutting, splicing and installation and other work incidental to the installation of waterstops.

Categories of work to be paid under this clause are as follows:

Description	Unit of Measurement
Water Stop, 200 mm Wide	m