2.6.2 Material Requirements

2.6.2.1 Topsoil

Topsoil shall be clean friable soil free of stones larger than 20 mm and free of weed or other deleterious matter.

2.6.2.2 Grass Sod

The sod shall consist of a healthy, dense and well rooted growth of living grass with roots surrounded by topsoil and shall not contain weeds or other undesirable plants.

The grass sod shall be cut into uniform squares approximately 300 mm and shall have a minimum thickness of 50 mm (excluding grass blades). The type of grass to be used shall be subject to the approval of the Engineer.

2.6.3 Method of Construction

2.6.3.1 Sodding

The surface of the area to be sodded shall be trimmed to the profile as shown on the drawings to the approval of the Engineer.

Units of grass sod shall be placed in uniform rows with the sides of adjacent sods in close contact to each other.

Unless otherwise required, the sod on slopes shall be laid horizontally, beginning at the bottom of the slopes and working upwards.

The areas to be sodded shall be as shown on the Drawings or as specified by the Engineer. The surface of the areas to be sodded shall be loosened and brought to a reasonably fine texture to a depth of approximately 20 mm. The bed upon which the sod is to be placed shall be moistened to the loosened depth, if not naturally sufficiently moist, and the sod shall be placed thereon within 24 hours after having been cut.

On all slopes steeper than one vertical to three horizontal the sod shall be pegged with stakes, 200 - 300 mm in length, spaced as required by the nature of the soil and steepness of slope. Stakes shall be driven into the sod at right angels to the slope until flushed with the bottom of the grass blades.

After the placement has been completed, the surface shall be cleared of loose sod, excess soil, or other foreign material, whereupon a thin layer of topsoil shall be scattered over the sod as a top dressing and the areas shall then be thoroughly moistened by sprinkling with water.

The Contractor shall regularly water and maintain sodded areas in satisfactory condition for the duration of the Contract and until final acceptance of the work by the Engineer.

2.7 MEASUREMENT AND PAYMENT

2.7.1 Stripping of Topsoil

Measurement shall be made of the volume of topsoil stripped in accordance with the requirement of clause 2.3 of the Technical Specification.

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 and any other associated costs.

The following pay items shall be measured and paid under this clause:

Pay Item No.	Description	Unit of Measurement
B.4.1	Stripping of Topsoil, 250 mm thick	m^3
B.6.1	Stripping of Topsoil, 250 mm thick	m^3
C.2.2	Stripping of Topsoil, 250 mm thick	m^3

2.7.2 Excavation

2.7.2.1 Excavation below Water Level

Measurement of the volume of Excavation below Water Level will be made using the average end area method of calculation for that portion of the volume of channel excavation below the nominal water level as defined in clause 2.4.1. Measurement for payment shall not be made of over-excavation beyond the lines, levels and profiles shown on the drawings.

Payment shall be made at the rate entered in the Bill of Quantities and shall include the entire cost of completing the excavation from the approved original surface levels down to the lines, levels and profiles shown on the drawings including materials, labour, equipment, transportation and any other associated costs.
No payment shall be made for over-excavation

Payment shall be deemed to include allowance for the cost of:

1) excavation through any material and to any depth
2) trimming to the correct profiles, lines and levels as shown in the Drawings
3) separating and setting aside those excavated materials suitable for re-use for other purposes and transporting to spoil those materials unsuitable for re use
4) transporting, for a distance of up to six (6) kilometres one-way, excavated materials to spoil dumps, spoil disposal areas, stockpiles or to areas to be filled with approved material..
5) preparation, clearing and operation of spoil disposal areas as described in this Specification.

The following pay items shall be measured and paid under this clause:

Pay Item No.	Description	Unit of Measurement
B.2.1	Excavation below Water Level (Low water level shown on the cross sections)	m^3
B.3.1	Excavation below Water Level (Low water level shown on the cross sections)	m^3

2.7.2.2 Excavation above Water Level

Measurement of the volume of Excavation above Water Level will be made using the average end area method of calculation for that portion of the volume of channel excavation below the nominal water levels as defined in clause 2.4.1. Measurement for payment shall not be made of over-excavation beyond the lies, levels and profiles shown on the drawings.

Payment shall be made at the rates entered in the Bill of Quantities and shall include the entire cost of completing the excavation above water level including materials, labour, equipment, transportation and any other associated costs.

Payment shall be deemed to include allowance for the cost of:

1) excavation through any material and to any depth
2) trimming to the correct profiles, lines and levels as shown in the Drawings
3) separating and setting aside those excavated materials suitable for re-use for other purposes and transporting to spoil those materials unsuitable for re use
4) transporting, for a distance of up to six (6) kilometres one-way, excavated materials to spoil dumps, spoil disposal areas, stockpiles or to areas to be filled with approved material..
5) preparation, clearing and operation of spoil disposal areas as described in this Specification.

No payment shall be made for over-excavation.

The following pay items shall be measured and paid under this clause :

Pay Item No.	Description	Unit of Measurement
B.2.2	Excavation above Water Level (Low water level shown on the cross sections)	m^3
B.3.2	Excavation above Water Level (Low water level shown on the cross sections)	m^3

2.7.2.3 Soft Rock Excavation

Measurement of the volume of Soft Rock Excavation based on survey data, drawings and computations approved by the Engineer.

Payment shall be made at the rate entered in the Bill of Quantities and shall include the entire cost of completing the work including materials, labour, equipment, transportation and any other associated costs.

The following pay items shall be measured and paid under this clause:

Pay Item No.	Description	Unit of Measurement
B.2.3	Soft Rock Excavation	m^3
B.3.3	Soft Rock Excavation	m^3
E.3.2	Soft Rock Excavation	m^3

2.7.2.4 Structural Excavation

Measurement shall be made of the volume of materials acceptably removed, measured in the cubic meters in its original position and computed by the average end area method. Measurement shall include authorised excavation of unsuitable material below grade. An allowance, not exceeding 600 mm, unless otherwise shown in the Drawings, may be provided outside the neat lines shown on the Drawings, where formwork for structures is necessary.

Payment shall be made for the quantity of work, accepted and measured as provided above, at the rate entered in the Bill of Quantities, and shall include the entire cost for furnishing all, shoring, and other related temporary work except work items measured separately in the Bill of Quantity and for all materials, labour, plant, tools and incidentals necessary to complete the work in accordance with the Drawings and these Specifications and as directed by the Engineer.

For structural excavation in waterway channel, separate payment will be made for coffering and dewatering which is paid elsewhere and the rate for structural excavation will not include for such.

For structural excavation outside of the river channel where coffering and dewatering is not provided as a separate pay item, the price shall include the cost of the necessary coffering and dewatering to complete the structural excavation.

The following pay items shall be measured and paid under this clause:

Pay Item No.	Description	Unit of Measurement
B.5.1	Structural Excavation	m^3
C.2.1	Structural Excavation	m^3
D.2.1	Structural Excavation	m^3
D.3.1	Structural Excavation	m^3
D.4.1	Structural Excavation	m^3
D.5.1	Structural Excavation	m^3
D.6.1	Structural Excavation	m^3
D.7.1	Structural Excavation	m^3
D.8.1	Structural Excavation	m^3
D.9.1	Structural Excavation	m^3
E.2.1	Structural Excavation	m^3
E.3.1	Structural Excavation	m^3
F.2.1	Structural Excavation	m^3
F.3.1	Structural Excavation	m^3
F.4.1	Structural Excavation	m^3
F.5.1	Structural Excavation	m^3
G.2.1	Structural Excavation	m^3
H.2.1	Structural Excavation	m^3
H.3.1	Structural Excavation	m^3
H.4.1	Structural Excavation	m^3
H.5.1	Structural Excavation	m^3
H.6.1	Structural Excavation	m^3
H.7.1	Structural Excavation	m^3
H.8.1	Structural Excavation	m^3
I.2.1	Structural Excavation	m^3

2.7.3 Fill

2.7.3.1 Embankment and Earth Fill

Measurement of the volumes of the various items of earth fill and embankment shall be made of the actual volume in cubic meters as determined by the measurement taken before and after filling operation. No measurement and payment shall be made for unauthorised filling outside the lines shown on the Drawings.

Payment shall include the cost of quarrying (in case of borrow), sorting, grading, handling, hauling, placing, watering, levelling, compacting and testing of the materials of in-place fill. Payment shall also include cost of preparation for surface and trimming of slopes and all labour, materials and equipment necessary to complete the work.

The following pay items shall be measured and paid for under this clause:

Pay Item No.	Description	Unit of Measurement
B.4.2	Embankment	m^3
B.6.2	Earth Fill	m^3
C.2.3	Embankment at the River Side Front of Floodwall	m^3
F.2.3	Embankment for Dike	m^3
F.3.3	Filling Existing Open Channel	m^3
F.5.2	Embankment for Dike	m^3
H.7.2	Embankment	m^3
H.8.2	Embankment	m^3

2.7.3.2 Soil Filling

Measurement of the volume of soil filling placed in accordance with clause 2.5.10 shall be made by computing the volume contained between the planes of the upper and lower surfaces of the cylindrical gabions and then deducting the volume occupied by the volume of the cylindrical gabions.

Payment shall be made at the rate entered in the priced Bill of Quantities and shall include the cost of all material, labour and equipment to complete the work in accordance with the specification.

The following pay items shall be measured and paid for under this clause:

Pay Item No.	Description	Unit of Measurement
D.2.12	Soil Filling	m^3
E.2.18	Soil Filling	m^3
E.3.15	Soil Filling	m^3
F.3.12	Soil Filling	m^3
G.2.20	Soil Filling	m^3
H.3.11	Soil Filling	m^3
H.4.9	Soil Filling	m^3
H.5.9	Soil Filling	m^3

2.7.3.3 Backfill with Selected Soil

Measurement shall be made of the volume of the backfill for backfill with the various materials as described in clause 2.5.9. Measurement will not be made of the volume of backfilling of structural excavation beyond the limits described in clause 2.4.2.4 of the Technical Specification.

Payment will be made at the rate entered in the Bill of Quantities and shall include the entire cost of completing the work including material, labour, equipment, transportation and any other associated costs.

The following pay items shall be measured and paid for under this clause:

Pay Item No.	Description	Unit of Measurement
B.5.2	Backfill with Selected Soil	m^3
C.2.5	Backfill with Selected Soil	m^3
D.2.2	Backfill with Selected Soil	m^3
D.4.2	Backfill with Selected Soil	m^3
D.5.2	Backfill with Selected Soil	m^3
D.5.3	Backfill with Gravel	m^3
D.6.2	Backfill with Selected Soil	m^3
D.6.3	Backfill with Gravel	m^3
D.7.2	Backfill with Selected Soil	m^3
D.9.2	Backfill with Selected Soil	m^3
E.2.2	Backfill with Selected Soil	m^3
E.2.3	Replacement of Base Soil under the Ground Sill with Selected Soil	m^3
E.3.3	Backfill with Selected Soil	m^3
F.2.2	Backfill with Selected Soil	m^3
F.3.2	Backfill with Selected Soil	m^3
F.4.2	Backfill with Selected Soil	m^3
F.5.7	Backfill with Selected Soil	m^3
G.2.2	Backfill with Selected Soil	m^3
H.3.2	Backfill with Selected Soil	m^3
H.4.2	Backfill with Selected Soil	m^3
H.2.2	Backfill with Selected Soil	m^3
H.5.2	Backfill with Selected Soil	m^3
H.6.2	Backfill with Selected Soil	m^3
I.2.2	Backfill with Selected Soil	m^3

2.7.3.4 Gravel and Rubble Stone Bedding and Filling

Measurement shall be made of the volume of gravel or rubble stone bedding or filling as described in clauses 2.5.12 and 2.5.13.

Payment will be made at the rate entered in the priced Bill of Quantities and shall include the entire cost of completing the work including material, labour, equipment, transportation and any other associated costs.

The following pay items shall be measured and paid for under this clause:

Pay Item No.	Description	Unit of Measurement
B.5.3	Gravel Bedding	m^3
C.2.6	Gravel Bedding	m^3
D.2.3	Gravel Bedding	m^3
D.4.3	Gravel Bedding	m^3
D.7.3	Gravel Bedding	m^3
D.9.9	Gravel Bedding	m^3
E.2.19	Gravel Bedding	m^3
F.3.4	Gravel Bedding	m^3
E.3.4	Gravel Bedding for Main Body and Side Wall	m^3
E.3.6	Gravel Bedding for Revetment	m^3
F.4.3	Gravel Bedding	m^3
F.5.4	Gravel Bedding	m^3
G.2.4	Gravel Bedding	m^3
H.2.4	Gravel Bedding	m^3
H.3.4	Gravel Bedding	m^3
H.4.3	Gravel Bedding	m^3
H.4.11	Gravel Filling	m^3
H.5.4	Gravel Bedding	m^3
H.6.4	Gravel Bedding	m^3
I.2.3	Gravel Bedding	m^3
H.6.5	Rubble Stone Bedding	m^3
H.3.5	Rubble Stone Filling	m^3
D.9.4	Rubble Stone Filling	m^3
F.3.14	Rubble Stone Filling	m^3
G.2.19	Rubble Stone Filling	m^3
H.5.12	Rubble Stone Filling	m^3
H.6.12	Rubble Stone Filling	m^3
I.1.2.11	Rubble Stone Filling	m^3

2.7.4 Sodding

Measurement shall be made of the area of solid sodding completed in accordance with clause 2.6 of the Technical Specification.

Payment will be made at the rate entered in the priced Bill of Quantities and shall include the entire cost of completing the work including materials, labour, equipment, transportation, maintenance and any other associated costs:

Payment will be made as follows:
- Payment will be made at 60% of the rate in the Bill of Quantities.

-The remaining 40% shall be paid on satisfactory establishment of the sodding.

The following pay items shall be measured and paid for under this clause:

Pay Item No.	Description	Unit of Measurement
B.4.3	Solid Sodding	m^2
C.2.4	Solid Sodding	m^2
D.10.1	Solid Sodding	m^2
F.2.4	Solid Sodding	m^2
F.5.3	Solid Sodding	m^2
H.7.5	Solid Sodding	m^2
H.8.4	Solid Sodding	m^2

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SECTION TS 3. CONCRETE WORKS

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 channel and dike works, the raising of the existing floodwall, protection works for the river bank and river bed, river amenity facilities, drainage outlet works 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's Representative 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's Representative, 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 (K 250 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.
3. Concrete to be paced under water shall have a minimum cement content of 400 kg/m^3.
4. 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 of 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:

	AASHTO Test method	Percentage 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:

	AASHTO Test method	Percentage 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 9 of this 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 Masonry Structures and Bonding of New Concrete

Where applicable, the plastered surfaces of existing masonry structures shall be chipped back as shown on the Drawings for a minimum depth of 20 mm in order to expose a sound masonry or mortar surface. Any cracked or damaged masonry remaining after chipping shall be removed and replaced with new concrete or masonry to the satisfaction of the Engineer.

The chipped surfaces of existing masonry 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.