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DIVISION 3 CONCRETE WORKS

SECTION 3000 CONCRETE

3001 General

(1) General

This section covers the material, workmanship, equipment and methods to be used for the production of concrete and the requirements for the conveyance, placing, curing and finishing of the concrete. Except where otherwise approved by the Engineer, ready-mixed concrete shall not be used.

Unless otherwise specified, all materials, methods and procedures for concrete works shall conform to applicable standards of the American Society for Testing and Materials (ASTM), where not covered by ASTM, such materials, method and procedures shall conform to Recommend Practices of the American Concrete Institute (ACI).

(2) Scope of Works

The Contractor's scope of concrete shall include services and furnishing of all plant, design, labour, materials, equipment, consumables required for the execution of concrete. The Works include, but are not limited to, the following:

- Concrete
- Temporary protective measures as required
- Installation and provision of all accessories such as joints, waterstops, inserts and finishing as required, including interfaces for structural, mechanical and electrical equipment.
- Dewatering for concrete works
- Construction design as required

3002 Applicable Codes and Standards

The concrete works shall conform to the following codes, standards and specifications or other equivalent codes and standards subject to approval of the Engineer, except as may be amended in this Specification:

The following standards and other publications are referred to in this section:

ACI	214	Guide for Evaluation of Strength Test Results of Concrete
ACI	304	Recommended Practice for Measuring, Mixing, Transporting and Placing Concrete
ACI	305	Hot Weather Concrete placing

ASTM	C	39	Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens
ASTM	C	40	Standard Test Method for Organic Impurities in Fine Aggregates for Concrete
ASTM	C	88	Standard Test Method for Soundness of Aggregates by Use of Sodium Sulphate or Magnesium Sulphate
ASTM	C	94	Standard Specification for Ready-Mixed Concrete
ASTM	C	109	Standard Test Method for Compressive Strength of Hydraulic Cement Mortars
ASTM	C	117	Standard Test Method for Materials Finer than 75- μ (No.200) Sieve in Mineral Aggregates by Washing
ASTM	C	127	Standard Test Method for Specific Gravity and Absorption of Coarse Aggregates
ASTM	C	128	Standard Test Method for Specific Gravity and Absorption of Fine Aggregates
ASTM	C	131	Standard Test Method for Resistance to Degradation of Small-Size Coarse Aggregate by Abrasion and Impact in Los Angeles Machine
ASTM	C	136	Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates
ASTM	C	150	Standard Specification for Portland Cement
ASTM	C	151	Standard Test Method for Autoclave Expansion of Portland Cement
ASTM	C	185	Standard Test Method for Air Content of Hydraulic Cement Mortar
ASTM	C	191	Standard Test Method for Time of Setting of Hydraulic Cement by Vicat Needle
ASTM	C	204	Standard Test Method for Fineness of Portland Cement by Air Permeability Apparatus
ASTM	C	227	Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations
ASTM	C	260	Standard Specification for Air-Entraining Admixtures for Concrete
ASTM	C	451	Standard Test Method for Early Stiffening of Portland Cement (Paste Method)
ASTM	C	494	Standard Specification for Chemical Admixtures for Concrete

3003 General Requirements

(1) Submittals

Submittals listed herein are related to items, which require the consent of the Engineer and are to be prepared by the Contractor before the appropriate work may proceed. The Contractor shall submit to the Engineer updated and detailed plans and descriptions, consistent with those submitted with his tender and any subsequent amendments and editions agreed to by the Engineer and the Contractor, of the following:

(a) Aggregates Processing Plant:

Description, flow diagrams and drawings in sufficient details to indicate layout, type and capacity of crushing, screening, washing, conveying and other aggregate processing and handling equipment, including standby equipment.

(b) Batching and Mixing Plants:

Description, type and capacity, flow diagrams, and drawings of the plants showing location and layout, and details of the equipment the Contractor intends to use to determine and control the amount of each separate concrete ingredient and mixing thereof into uniform mixture where appropriate, including standby equipment.

(c) Transport and Placing of Concrete:

Full details of the equipment and methods for transporting the concrete from the concrete plant to the final point of placing, including numbers, type and capacity of transport vehicles and concrete pumps, and details of standby plants to be installed.

(d) Sampling and Testing Materials:

List and details of equipment for sampling and testing detailed program for quality control of concrete work and qualification and experience of the proposed personnel.

The Contractor shall submit to the Engineer following notifications based on the results of the preliminary material testing, if not otherwise agreed:

- a) Notifications of the mill or mills from which cement will be obtained and whether cement will be ordered in bulk or bags. If cement is to be obtained from several mills, the estimated amount of cement from each mill and the proposed schedule of shipment shall be stated.
- b) Notification of the source or sources from which aggregates will be obtained. If aggregates are to be obtained from several sources, the estimated amount of aggregates from each source shall be stated.
- c) Notification of the source, method of delivery, and storage of water for concrete manufacture.
- d) Notification of any admixtures and pozzolans which the Contractor proposes to use, manufacturers thereof, and information about the chemical names of the principal active ingredients and the effects of under or over dosage. Should the Contractor intend to use an accelerator in any concrete work for his own convenience, he shall give full details of the type, dosage, influence on construction, and the cost savings involved.
- e) Details of materials for formwork and surface finishes, treatment of construction joints, and construction techniques which the Contractor proposes to use in order to achieve the required concrete surfaces and allowable tolerances.

- f) Notification of the mill or mills from which steel reinforcement is to be obtained. If reinforcement is to be obtained from several mills, the estimated weight from each mill and the proposed schedule of shipment shall be stated.

Prior to procuring or dispatch to the Site of the particular item of work to which the submittal relates, the Contractor shall submit to the Engineer following:

- a) Detailed information on physical properties, performance, including the certified copies of reports of all tests made by the manufacturers of waterstops, expansions joint filler, and joint sealing compounds along with material samples of the products.
- b) Details of curing compounds.

Drawings showing the location of construction joints proposed by the Contractor which differ from those shown on the Construction Drawings, including formwork and reinforcement details, shall be submitted to the Engineer at least 30 calendar days prior to commencement of that particular structure.

(2) Drawings

(a) General

After approval or comments by the Engineer, all drawings shall be stamped by the designer as follows: "Final drawing approved for construction". Only drawings identified as such will be released on site for construction. If not otherwise agreed the reference and date of approval shall be mentioned on the drawing stamp.

All drawings shall comply with the requirements of the contract.

(b) Formwork drawings

Formwork drawings shall provide all information required on site for the erection of formwork and shall define the geometrical data determining the final shapes to be given to all concrete constructions and structures.

These drawings shall include full details, such as dimensions of structures, recesses, slots, embedded items duly identified and alike. These drawings shall make references to design live loads, corresponding construction drawings and pertaining information.

For buildings, elevations will be referred to the ground floor +/- 0.00 level defined in the general plant layout. Furthermore, two perpendicular building axis shall be connected to the local site co-ordinates and the direction of the North shall be shown.

(c) Reinforcement Drawings

These drawings shall give full geometrical information for proper location, diameter, and shape of the reinforcement designed for the structure. Each bar shape shall be identified with an item number.

(d) Bar Bending Schedules

Bar bending schedules shall give full information for bending all bars in a workshop. Each bar shape shall be clearly identified with an item number. The bar bending schedule shall show the shape and geometrical dimension of each item, diameter, number of bars per item, and the computed weights and lengths of the reinforcement. Reference for each item shall be made to the corresponding reinforcement drawing.

The bar bending schedules will not show additional bars required either as spacers or steel chairs. The Contractor shall however provide such bars.

3004 Materials and Workmanship

(1) Plant

The Contractor shall submit to the Engineer for approval a complete set of drawings together with a detailed description of his proposed plant and equipment for concrete production, transportation and placement of concrete, and method of operation. This submission shall be made before any order to purchase, fabricate or ship such plant and equipment is made.

(2) Cement

(a) General

Cement shall be supplied from approved sources. The use of different cement types shall be subject to the approval of the Engineer, and each type shall be stored separately.

Cement, which does not comply with the specified requirements or is damaged in consignment, handling or storage, shall be promptly removed from the Site.

Cement shall be transported from the port or mill to the Site in adequately designed weather-tight trucks, or other means where cement will be protected from exposure to moisture.

Bagged cement shall be stored in weather-proof buildings with a raised, well ventilated wooden floor, and placed so that each consignment can be segregated if required more than 1.50 m high. The bags or packages shall incorporate an impregnated bitumen layer. Cement shall not be stored out of doors, except for immediate use, and in such event shall be protected during storage and handling by waterproof covers and a raised floor. Unused cement must be placed in the storage buildings.

Cement delivered in bulk shall be stored in suitably designed containers and protected from atmospheric moisture and condensation. Excessive storage shall be avoided.

Cement shall be used in approximately chronological order in which it has been received at the Site. Storage of cement shall be limited to 90 days in bags and 150 days in bulk. Cement that has been in storage for longer than these periods or which may have absorbed moisture shall

not be used unless it has been re-tested by the Contractor and approved. Cement that has become partially or fully lumpy or caked shall not be used.

The Contractor shall keep and make available to the Engineer records of the date, amount, and storage location of each delivery of cement and of the part of the Works in which it was used and shall provide facilities for checking the stock of cement.

The Contractor is solely responsible for the timely supply of cement meeting the requirements of these specifications and the Works. The delay due to the lack of suitable cement will not give the Contractor any right for the extension of time for the completion of Works, or any claims resulting here from.

(b) Cement Types

(i) Portland Cement Type I

Portland cement shall conform to ASTM C-150. Cement Type I (regular) shall be used for all general concrete construction. Heat of hydration should be controlled by use of additives such as fly ashes or similar agents.

(ii) Portland Cement Type V (Sulphate Resistant Cement)

Cement Type V shall be used for all foundations and structural components below grade elevation, and all structures on contact with concentrated brine or seawater or exposed to weather. Heat of hydration should be controlled by use of additives such as fly ashes or similar agents.

(c) Testing Cement at Source

The Contractor shall arrange for mill test sheets covering physical and chemical testing by the manufacturer for each consignment of cement and shall obtain the consent and cooperation for the manufacturer for independent testing to be carried out for samples obtained at the Site from time to time as directed by the Engineer.

The following tests shall be carried out in accordance with the ASTM Standards shown and the results shall be forwarded to the Engineer on each consignment of cement:

a) Soundness .	ASTM C 151
b) Time of Setting	ASTM C 191
c) Compressive Strength	ASTM C 109
d) False Set	ASTM C 451
e) Fineness Tests	ASTM C 204
f) Air Content of Mortar	ASTM C 185

The complete test data as specified herein shall be supplied to the Engineer prior to shipment of cement to the Site.

(d) Testing Cement at Site

The Contractor shall provide access to the Engineer for obtaining samples from storage as required for testing. This testing may include any or all of the tests specified in clause “(c) Testing Cement at Source” . Any consignment from which a sample has been obtained and which does not meet the requirements of the Specifications, shall be deemed defective and the cement shall be removed from the Site as directed by the Engineer.

(e) Storage of Cement

Sufficient weatherproof, properly ventilated storage, including covered unloading bays, shall be provided at the Site to ensure that no delay is caused due to shortage of cement and that sampling can be carried out at least 7 days prior to use in the Works.

Exterior surfaces of the cement silos shall be painted with white or other heat reflecting paint. Cement shall be used in the sequence in which it arrives. Silos shall be voided and cleaned out at least once every three months. If cement becomes lumpy due to partial hydration, it shall be removed from the Site immediately. The maximum temperature of cement entering the batching plant shall be less than 43 degrees Centigrade.

(3) Water

Water for concrete shall be clean, potable and free from injurious amounts of oil, alkali, salts, acid, silt, organic materials, or other deleterious substances. Sources and treatment of water shall be approved by the Engineer.

(4) Aggregates

(a) General

Concrete aggregates will be obtained from local suppliers subjected to the approval of the Engineer. Unless otherwise specified, the specific gravity of saturated surface-dry aggregates shall not be less than 2.50 when tested in accordance with ASTM C127 and C128.

Immediately after the delivery of aggregates has commenced, the Contractor shall send representative samples of all sizes of aggregate to the laboratory for testing as required by the Engineer. Further samples required for testing and control purposes shall be supplied as directed by the Engineer. The laboratory shall be proposed by the Contractor and approved by the Engineer.

(b) Storage of Aggregates

All aspects of aggregate handling and storage are subjected to the approval of the Engineer and shall be such as to eliminate segregation and breakage and to prevent contamination by deleterious matter or aggregates of other sizes, so that adequate supplies are available in advance of the requirements.

Each size of aggregate shall be stockpiled at approved locations, which shall be cleared and

stripped. Stockpiles shall be sufficiently removed from each other to prevent the material at the edges of the piles from becoming intermixed. The bottom portion of the stockpiles within 300 mm of the ground shall not be used for production of concrete.

Stockpiles shall be free-draining and coarse aggregate stockpiles shall be kept continuously moist by spraying as necessary to control the water content as specified in this section. Sprays shall be arranged so that the stockpiles are wetted uniformly.

The moisture content of the fine aggregate as delivered to the mixer shall be controlled so as not to exceed a value of 6.0 percent, expressed as a percentage by weight of the saturated surface dry aggregate. Variations in the percentage of free moisture in any aggregates shall be limited to less than 1.0 percent in any hour of mixing plant operation.

The Contractor may accomplish the required moisture control by use of covered storage, mechanical dewatering devices or any other satisfactory means or combination thereof.

(c) Fine Aggregates

The fine aggregates shall consist of clean, hard, dense, durable, uncoated rock fragments. Fine aggregate shall be removed from the Site immediately if it fails to meet any of the following quality requirements:

- a) Organic Impurities in Sand (ASTM C40): Color no darker than the specified standard.
- b) Sodium Sulfate Test for Soundness (ASTM C88): Shall have 8 percent maximum weighted average loss, by weight.
- c) Deleterious Substances : As shown in Table 300-1

Table 3000-1 Allowable Percentages of Deleterious Substances in Fine Aggregate

	Maximum percent by weight, as batched (%)
Material passing No.200 sieve (ASTM C117)	2
Lightweight material (ASTM C123,using a solution of zinc chloride)	2
Friable particles (ASTM C142)	1
Other deleterious substance south as mica, coated grains, soft-flaky particles, and loam	2
Sum of all the above deleterious substances	5

The fine aggregate shall be well-graded, and when tested using standard sieves (ASTM C136), shall conform to the limits in Table 300-2.

Table 3000-2 Fine Aggregate Grading Requirements

Sieve No.	Percent, by weight, retained on sieve (%)
4 (4.76mm)	90 to 100
8 (2.38mm)	80 to 100
16 (1.19mm)	50 to 90
30 (0.59mm)	25 to 60
50 (0.297mm)	10 to 35
100 (0.149mm)	2 to 10

Samples of fine aggregate together with coarse aggregates and cement to be used for the production of concrete shall be tested according to ASTM C227.

(d) Coarse Aggregates

Coarse aggregates shall be graded according to Table 3000-3 when tested in accordance with ASTM C117 and C136.

Table 3000-3 Coarse Aggregate Grading Requirements

Nominal Aggregate Size (mm)	Percent finer than, by Weight	
	40 mm to 5mm	20 mm to 5 mm
50	100	
40	95 -100	
25	-	100
20	35-70	90 -100
10	10 - 30	20 -55
5	0 - 5	0 -10

The weight of coarse aggregate having the ratio of largest dimension to smallest dimension of more than 3 shall be limited to not more than 20 percent.

The coarse aggregate shall consist of clean, hard dense, durable uncoated rock fragments. Coarse aggregate shall be removed from the Site immediately if it fails to meet any of the following quality requirements:

- a) Los Angeles Abrasion Loss
(ASTM C131, using grading A) Shall have a 10 percent maximum loss of weight at 100 revolutions, or 40 percent maximum loss of weight at 500 revolutions.

- b) Sodium Sulfate Test of Soundness
(ASTM C88) Shall have 10 percent maximum weighted average loss, by weight, after 5 cycles.

- c) Deleterious Substances. These substances, in any size of coarse aggregate, are as shown in Table 3000-4.

Table 3000-4 Allowable Percentages of Deleterious Substances in Coarse Aggregate

	Maximum percent by weight, as batched (%)
Light weight material (ASTM C123, using a solution of zinc chloride)	2
Friable particles (ASTM C142)	0.5
Other deleterious substances	0.5
Maximum allowable sum of all the above deleterious substances	2

Samples of coarse aggregates, together with fine aggregates and cement to be used for the production of concrete shall be tested according to ASTM C227.

(5) Admixtures and Additives

(a) General

The use of all admixtures shall be subjected to the written approval of the Engineer. The manner of use, storage, handling and measurement may also be subjected to controls in addition to those specified below, depending on the manufacturer's recommendations and test results. Multi-purpose admixtures shall not be used.

(b) Air Entraining Agents

An approved air entraining agent shall be used to produce the specified amount of stable entrained air in the concrete mixture, and shall conform to the requirements of ASTM C260. The required air content of the concrete is as follows:

Maximum Aggregate Size (mm)	Total Air (%)
40	5 ± 1
20	6 ± 1
Grout	as directed by the Engineer

(c) Water Reducing Admixture

A water reducing admixture that does not retard the initial set of the concrete shall be added to the concrete mix during mixing. The amount of admixture to be added shall be as directed by the Engineer. The admixture shall conform to the requirements of ASTM C494.

(d) Initial Set Retarding Admixture

An initial set retarding admixture shall be added to the concrete mix during mixing in order to obtain the necessary retardation of the initial set of the concrete. The amount of admixture to be added shall be as directed by the Engineer. This admixture shall conform to the requirement of ASTM C 494.

(e) Expansive and Non-shrink Additives

An expansive and non-shrink additive shall be added to the concrete mix of the secondary

concrete in order to prevent shrinkage cracks and to increase water tightness, tensile strength under restrained conditions and shearing strength. The amount of additives to be added shall be as directed by the Engineer. This additive shall not generate hydrogen gas when it starts a chemical reaction and shall conform to the requirements of ASTM C494.

(f) Plasticizer

Concrete plasticizers are admixtures for concrete, which shall decrease the amount of water and increase the strength of concrete. In addition they shall improve the workability at the concrete.

The application of the plasticizer shall conform to ASTM C494. Special care shall be taken when using at high temperatures.

(g) Heat of Hydration

Fly ashes to reduce the heat of hydration to meet the specifications.

(h) Calcium Chloride

The use of calcium chloride or of admixtures containing calcium chloride is prohibited.

(i) Compatibility

The compatibility of admixtures, where more than one is used, shall be proved to the satisfaction of the Engineer and satisfactory test results shall be obtained before incorporation in the works.

(j) Storage and Dispensing of Admixtures and Additives

Admixtures shall be stored in suitable weatherproof buildings. Admixtures in solution shall be stored at a temperature not higher than 35 degrees C. Powdered admixtures shall be put into solution prior to use in accordance with the manufacturer's recommendations.

Accurate automatic dispensing equipment shall be provided for the measurement of materials and for the introduction of the admixtures into the mixer. The individual admixtures shall be added separately to the concrete in the mixer during the first half minute of the mixing cycle.

(6) Workmanship

All workmanship shall be of the best quality in each respective category of the Works. Except where otherwise stated, or approved by the Engineer, all materials used in the Works shall be of the best quality, in the respective kinds specified or described in the Specifications, Drawings and Bill of Quantities, and shall comply wherever possible with the current issue of the reference Standards or other equivalent approved national standards, subject to the approval of the Engineer.

3005 Concrete and Mortar Mix Design

(1) Mix Proportions

The Contractor shall propose mix proportions for all kinds and classes of concrete, which he intends to use in compliance with the following requirements.

Unless otherwise approved by the Engineer, the net water-cement ratio for concrete of the respective structure shall be less than 0.6.

Any kind of concrete mix proportions shall be approved by the Engineer in the light of the trial mix and its results as specified. The mix proportions may be modified by the Engineer from time to time in accordance with the work conditions such as climate, concrete placing method and so on. The Contractor shall not change or modify any mix proportion without written consent of the engineer.

Compliance with concrete compressive strength requirements shall be based on compressive strength tests carried out by the Contractor on standard 150 mm diameter by 300 mm high test cylinders of concrete at the age of 28 days in accordance with ASTM C 39. Coarse aggregate over 50 mm size shall be removed from the concrete for the compressive strength test.

(2) Classification of Concrete

The major classes of concrete and the aggregate sizes and the workability of concrete for various types of construction are set out in Table 5.

The class of concrete to be used for respective structures are as indicated on the Drawings or directed by the Engineer.

Table 3000-5 Concrete Classification

Class of Concrete	Type of Construction	Design Strength 28 days (kg/cm ²)	Coarse Aggregate Max. siz (mm)	Slump Max. (cm)
A	Plain Concrete (1)	180	40	8~12
B	Plain Concrete (2)	225	20	8~15
C	Reinforced Concrete(1)	275	40	8~15
D	Reinforced Concrete (2)	275	20	12~15
E	Secondary Concrete	275	40	8~15
F	Lining Concrete	225	40	8~12
G	Building Concrete	300	20	8~12

The selection of concrete mix shall be such that the maximum size of aggregate shall not be larger than:

- a) One-fifth of the narrowest dimension between sides of forms;
- b) Three-quarters of the minimum clear spacing between reinforcement bars; or
- c) One-third the depth of slabs.

(3) Trial Mixes

At least 60 days prior to the start of permanent concrete work, the Contractor shall produce trial mixes for each of the classes of concrete specified, using the batching and concrete mixing plant provided for the execution of the Works. Such trial mixes shall be repeated until concrete complying with these specifications is produced.

(4) Dry Pack

The dry pack mix shall be proportioned by weight; one part cement to 2 1/2 parts of sand that will pass a No. 16 screen. Only enough water shall be used to produce a mortar that will stick together while being molded into a ball by slight pressure of the hands and will not exude water but will leave the hands damp.

(5) Mortar Mix

Mortar mix to be used for the construction works including joint treatment of concrete works shall be as follows:

Design of Mortar Mixing

Mortar Class	Cement	Sand	Remarks
Mortar A	1	10	Lining canal
Mortar B	1	5	Grouting for Stone Pitching
Mortar C	1	3	Pump room
Mortar D	1	3	Buildings
Mortar E	1	1.0 to 1.5	Steel pipe coating
Mortar F	Mortar mix for joint treatment shall have the same sand, cement and air proportions as the mortar used in the mix of the concrete at the joint.		

Note: Ratio between cement and sand are by weight.

Mortar to be used for repair work shall have the same sand, cement and air proportions as the mortar used in the mix of the concrete to be repaired.

3006 Field Quality Control

Concrete tests will be carried out by the Engineer in conformity with ASTM C 39 and test evaluation will be in accordance with ACI 214. The Contractor shall provide such assistance as may be required by the Engineer in procuring samples and transporting them to the field laboratory. Samples of fresh concrete will be obtained from the forms or as required by the Engineer.

Concrete samples taken for conducting strength test in accordance with ASTM C 39 consists of 3 or more samples per pour. The Contractor shall arrange for temporary storage of fresh cylinders at or near the forms and shall maintain and protect the same under moist curing conditions for a period of up to 24 hours after the completion of the relevant pour.

Where compressive strength tests are made to monitor form work removal, two additional cylinders will be prepared and field curing under similar but not more favorable conditions than those existing for the member represented shall be made.

3007 Batching

(1) Type of Plant

The Contractor shall provide at least one modern and dependable automatically or semi-automatically controlled batching plant at the pumping station. These plants shall be capable of supplying concrete at rates adequate to meet the requirements of the work schedule and shall be as approved by the Engineer.

(2) Measurement and tolerances

Cement shall be weighted separately on an individual scale. Water shall be weighted separately on an individual scale or it may be measured by volume. All other ingredients shall be measured by weight except that liquid admixtures may be measured by weight or volume. Each aggregate shall be measured separately. If water is measured by volume, two flow meters shall be installed in parallel so that no delay will result due to faulty operation of the meters.

3008 Mixing

Concrete shall be thoroughly mixed in a batch mixer of an approved size and type, which will ensure a uniform distribution of the component materials throughout the mass.

The entire contents of the mixer shall be discharge from the drum before materials for a succeeding batch are placed therein. The materials composing a batch shall be deposited simultaneously in the mixer.

Water for the batch should be released first and continue to flow while the solids are entering the mixer, and should have completed flowing shortly after the last of the solids of the batch have entered the drum. This flow shall not continue for more than the first 25 percent of the mixing time.

The first batch of concrete materials placed in the mixer at the beginning of each period of mixer operation shall contain a sufficient excess of cement, sand and water to coat the inside of the drum without reducing the required mortar content of the mix. Upon the cessation of mixing for a period equal to, or in excess of, 75 percent of the time interval of initial set of the mix, the mixer shall be thoroughly cleaned.

3009 Transportation

Concrete shall be transported from the mixers to the place of concrete placement by methods which will prevent segregation, gain or loss of materials, and which are such that the maximum difference in the slump of samples of concrete taken immediately after mixing and immediately after placement in the forms shall not exceed 25 mm.

Concrete shall be delivered to the forms not later than 45 minutes after the addition of mixing water. Where a set retarder is employed, this time may be extended at the discretion of the Engineer.

Where truck mixers are used, they shall be used in accordance with the applicable sections of ASTM C94 and ACI 304. Truck mixers, unless otherwise authorized by the Engineer, shall be of the revolving drum type, watertight and so constructed as to ensure a uniform distribution of materials throughout the mass of concrete being mixed. All solid materials and admixtures for the concrete shall be accurately measured and charged into the drum at the batching plant. The truck mixer shall be equipped with an in-line flow meter by which the equality of water added can be measured.

3010 Placing and Handling

(1) Cleaning

All equipment employed in the measuring, mixing, conveyance and placing of concrete shall be thoroughly cleaned prior to each use. Concrete waste deposited in or on the equipment shall be thoroughly removed immediately after each use.

In preparation for the placing of concrete, all sawdust, chips and other construction debris shall be removed from the interior of forms. Prior to placing concrete on construction joints, the joint surfaces shall be thoroughly cleaned and kept in a saturated surface dry condition and the concrete placing shall be preceded by a 10 to 20 mm - thick layer of cement mortar with sand and cement in the same proportion as the mortar in the concrete to be placed. Wood struts, stays or braces in the forms are prohibited. Struts, stays and braces serving temporarily to hold the forms in correct shape and alignment, pending the placing of concrete at their locations, shall be removed when the concrete placing has reached an elevation rendering their service unnecessary. These temporary members shall be entirely removed from the forms and not buried in the concrete.

(2) Placing

Concrete shall be placed so as to avoid segregation of the materials and the displacement of the reinforcement. The use of long troughs, chutes and pipes or conveyors, multiple or single, for conveying concrete from the mixer or hauling unit to the forms shall be permitted only upon written approval of the Engineer. In case an inferior quality of concrete is produced by the use of such conveyors, the Engineer may order discontinuance of their use and the

substitution of a satisfactory method of placing. Open troughs and chutes shall be steel or steel lined. Where steep slopes are required, the chutes shall be equipped with baffles or be in short lengths that reverse the direction of movement. Baffles or boxes or vertical drop pipes shall be arranged so that the concrete drops vertically from the delivery end of all conveying units and so that there is no segregation of the concrete mix. Free drop without control of trunks or baffles shall be limited to 1.5 m.

Buckets for placing of concrete shall have a discharge area not less than 60 percent of the cross-sectional area of the bucket. The discharge gates shall be positively closing, shall be maintained in a watertight condition and the rate of discharge shall be readily controlled without any consequent segregation of the concrete.

The use of pneumatic or pumping methods of placing and handling concrete shall be subjected to the approval of the Engineer. Prior to the use of such methods, the Contractor shall submit for the Engineer's approval the details of the equipment proposed, its arrangement and the proposed operating procedures. The Contractor shall produce and convey concrete using such equipment for the trial mixes until concrete is produced that conforms to the Specifications. Pumping methods shall comply with the recommendations of ACI 304, "Placing Concrete by Pumping Method". Water reducing admixture may be used to obtain high slump concrete without increasing of water cement ratio.

(3) Compacting

Concrete during and immediately after placing shall be thoroughly compacted. The compaction shall be done by mechanical internal vibration subjected to the following provisions.

Vibrators shall be electric or pneumatic power driven type and shall operate at speed, when immersed in the concrete, of not less than 9,000 revolution per minute for vibrating heads less than 10 cm in diameter and not less than 7,000 revolutions per minute for vibrating heads of 10 cm or greater in diameter.

The Contractor shall provide a sufficient number of vibrators with mechanical means of handling if necessary, to properly compact fresh concrete immediately after it is placed in the forms and shall maintain at least one spare vibrator at the form.

In concrete having a placing rate greater than 20 cu.m per hour, compaction shall be accomplished using vibrators of 100 mm or greater in diameter.

Vibrators shall be manipulated so as to thoroughly work the concrete around the reinforcement and embedded fixtures, and into corners and angles of the forms. Vibration shall be applied at the point of placement and in the area of freshly placed concrete. The vibrators shall be inserted into and withdrawn from the concrete slowly. The vibration shall be of a sufficient duration and intensity to thoroughly compact the concrete, but shall not be continued at any one point of the extent that excess water or grout appears. Application of vibrators shall be at points uniformly spaced and not further apart than twice the radius over which the vibration is visibly effective.

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. Vibrators shall not be used to transport concrete in the forms.

Concrete shall be placed in horizontal layers not more than 450 mm thick except as hereinafter provided. When less than a complete horizontal layer is placed in one operation, it shall be terminated using a vertical bulkhead. Each layer shall be placed and compacted before the preceding batch has taken initial set to prevent injury to the green concrete and to avoid surface separation between the batches. The provision for bonding successive courses of concrete shall all times be subjected to the Engineer's approval.

3011 Green-cutting

When successive lifts of concrete are to be placed, laitance shall be removed from the surface of the concrete of the previous lift by means of approved manners prior to pouring the subsequent lift. The timing of this operation shall be such that individual pieces of concrete aggregate are exposed but their bond with the underlying concrete will not be affected. If required by the Engineer, the surface shall be cleaned by surface chipping or wire brushing.

3012 Joints in Concrete

(1) General

Construction joints, expansion joints and contraction joints shall be located in the positions shown on the Drawings or as required by the Engineer. The Contractor shall not be permitted to form any additional joints or deviate from the joints indicated in the Drawings either in design or location, without the written approval of the Engineer. Joints at exposed surfaces of concrete shall be straight and continuous as shown in the Drawings or otherwise specified.

To prevent feather-edges, the construction joints at the tops of horizontal lifts near sloping exposed concrete surfaces shall be inclined near the exposed surface so that the angle between such inclined surface and the exposed concrete surface will not be less than 50 degrees.

Disturbance of the new surface at a joint during the early stages of hardening except as specified for green cutting is prohibited and no work or traffic on the new concrete will be permitted until the concrete has hardened sufficiently to withstand such treatment without injury.

All surfaces upon which, or against which, concrete are to be placed shall be in a saturated surface-dry condition prior to being covered by fresh concrete.

(2) Preparation

Prior to placement of new concrete, all surfaces upon which, or against which, concrete is to be placed, including surfaces of construction joints between successive concrete placements, shall be thoroughly cleaned of all loose particles, dried mortar or grout or other deleterious matter. Cleaning shall include through-washing using water and brush. Where directed by the Engineer, all laitance and loose or defective concrete not removed by green cutting operation shall be removed by surface chipping or wire brushing. The aggregate of formed surfaces of construction joints shall be exposed by surface chipping. On formed expansion and contraction joint concrete surfaces, the aggregate shall remain unexposed.

(3) Cold Joints

Cold joints shall be avoided. In the event of equipment breakdown, or if for any other reason continuous placing is interrupted, the Contractor shall thoroughly consolidate the concrete to a reasonably uniform and stable slope while it is plastic and if concreting is not resumed within 1 hour it shall be discontinued and not resumed until permitted by the Engineer. When concreting operations are resumed, the usual construction joint treatment shall be applied on the surface of the concrete at the joint, before being covered with fresh mortar and concrete.

3013 Curing of Concrete

All concrete shall be cured by maintaining its surface in a constantly moist condition for a period of at least 7 days after placing or until the surface is covered with fresh concrete. All surfaces shall be protected from the sun's rays for at least 5 days after placing.

The surface of concrete, shall be moistened by covering with water-saturated materials or by employing other effective means approved by the Engineer which will keep the surfaces to be cured continuously wet as soon as the concrete has hardened sufficiently to prevent damage.

Equipment for curing shall be available at the site before concrete placement is started and the water used for curing shall meet the requirements for water used for mixing concrete.

In case the Contractor proposes to use a membrane curing, he should submit the proposal to the Engineer for approval at least 60 days prior to be used.

Steel reinforcement projecting from any placement shall be positively tied to prevent movement and possible debonding during placement and shall be protected from all disturbances for at least 24 hours after completion of such placement.

3014 Temperature Control of Concrete in Hot Weather

The Contractor shall apply any or all of the recommendations contained in ACI 305, "Hot Weather Concreting", to control the temperature of concrete as directed by the Engineer, in order to avoid the detrimental effects of high temperatures to the concrete which becomes hard

or is already hardened.

- (1) When the shade air temperature is 35 degrees C and rising, the coarse aggregate shall be sprayed with water or cooled by appropriate means. Special precautions shall be taken during the entire concreting process so that the temperature of the concrete does not exceed 49 degrees C when it is placed.

Fresh concrete placed at these temperatures shall be carefully shaded from the sun's rays and wind to the satisfaction of the Engineer.

- (2) No concrete shall be mixed or placed when the shade air temperature reaches 40 degrees C or more unless proper measures are taken for cooling aggregates and mixing water.

All costs of provision for hot weather concreting shall be included in the unit price of the appropriate concrete works.

3015 Tolerance for Concrete Construction

Permissible surface irregularities for the various concrete surface finishes are specified in the section 3016 "Finishing", and are to be distinguished from tolerances as specified hereunder. The intent of this section is to establish tolerances that are consistent with modern construction practice, but which are governed by the effect that permissible deviation will have upon the structural action or operational function of the structure.

- (1) Subject to the requirements of section 3016 "Finishing" and except as otherwise shown on the Drawings or required by the Engineer, deviation of concrete from the lines, grades and dimensions shown on the Drawings will be permitted within the following limits:
- a) Variation in location from specified position in plan.
 ± 25 mm
 - b) Variation from centerline specified in plan for each structure.
For overall length ± 25 mm
For any span less than 9 m ± 10 mm
 - c) Variation from pump, specified batter, or specified curved profile for lines and surfaces of columns, walls, beams, buttresses, piers and similar members:
For any two successive intermediate points on the lines or surfaces separated by:

3 m	6 mm
6 m or more	20 mm
 - d) As (b) above, but for surfaces to be in contact with backfill:
twice the above dimensions
 - e) Variation from the level or from the elevations specified in plan:
 ± 6 mm

f) Variations in cross-sectional dimensions from those specified for columns, walls, beams, buttresses, piers and similar members:

-6 mm, + 12 mm

g) Variation in thickness of slabs, walls and similar members from that specified:

-6 mm, + 12 mm

(2) The Contractor shall be responsible for setting and maintaining concrete forms sufficiently within the specified tolerance limited and shall ensure that the concrete is completed within these limits. Concrete work that exceeds the specified tolerance limits shall be remedied or removed as required by the Engineer.

3016 Finishing

(1) General

Allowable deviations of concrete from the established lines, grades and dimensions shown on the Drawings or specified in section 3015 "Tolerances for Concrete Construction", are defined as tolerances and are to be distinguished from surface irregularities as defined hereunder.

The finished surfaces of concrete shall be true, sound, smooth and free from fins, offsets, pits, depressions, voids, blemishes and other defective concrete, and shall be in accordance with the requirements for the corresponding class of finish specified herein.

Finishing of concrete surfaces shall be performed only by skilled workmen.

Surface irregularities are classified as "abrupt" or "gradual". Offsets caused by displaced or misplaced from sheathing, lining or form sections, by loose knots in forms, or otherwise defective form lumber will be considered as abrupt irregularities and will be measured directly. All other irregularities will be considered as gradual irregularities and will be measured with a template consisting of a straightedge for plane surface or its equivalent for curved surfaces. The length of the template will be 1.50 m for testing formed surfaces and 3 m for testing unformed surfaces.

(2) Formed Surface Finishing

The classes of finish for formed concrete surfaces are designated by the use of the symbols F1, F2 and F3, and shall be as follows:

a) Finish F1:

The finish applies to surfaces upon or against which fill material or concrete is to be placed. The surfaces require no treatment after form removal except for repair of defective concrete and the specified curing. Surfaces to be submerged or below ground water level shall have all form-tie holes filled as directed by the Engineer.

b) Finish F2:

This finish is required on all formed surfaces not permanently concealed by fill materials or concrete and for which no other finishes are specified. This finish shall present a uniform appearance and no special surface treatment will be required other than the repair of defective concrete, the filling of fastener holes, the removal of abrupt irregularities in excess of 6 mm and the reduction of gradual irregularities so that they shall not exceed 12 mm for the length designated.

c) Finish F3:

The finish is designated for surfaces prominently exposed to public view where appearance is of special importance. On completion of the repair of defective concrete and filling of fastener holes, this finish shall present a surface of uniform appearance and texture. Surface irregularities shall not exceed 6 mm for gradual irregularities and abrupt irregularities exceeding 3 mm will not be permitted. In addition to the repair of defective concrete and the removal of fins, offsets and other irregularities, the surface shall, if the Engineer considers it necessary, be sack-rubbed to fill pits and air holes. Sack-rubbing shall be done as soon as the forms have been stripped and after any required patching and correction of major imperfections have been completed. The mortar to be used shall consist of 1 part cement to 2 parts by volume of sand passing a No. 16 US. Sieve and shall be mixed with water to a creamy consistency. If required by the Engineer, the Contractor shall add white cement to the mix in order to obtain a color and texture that will match the surrounding concrete surfaces. After surface treatment is completed, the specified curing shall continue for not less than 14 days.

(3) Architectural Finishing

Architectural finishing shall be referred to the Section 6600 "Architectural Finishing" of the Division 6 "Building Works".

(4) Unformed Surface Finishing

The classes of finishing for unformed concrete surfaces are designated by the use of the symbols U1, U2 and U3, except those for topping, and shall be as follows:

a) Finish U1 (Screened Finish) :

This is a screened finish used on surfaces that will be covered by fill materials or concrete. Finishing operations shall consist of sufficient

leveling and screening to produce even, uniform surfaces. Surface irregularities shall not exceed 10 mm.

Finish U1 is also used as the first stages of finishes U2 and U3.

b) Finish U2 (Floated Finish):

This is a floated finish used on surfaces not permanently concealed by fill materials or concrete. Finishing operations shall consist of sufficient leveling and screening to produce even surfaces in which the surface irregularities shall not exceed 6 mm. Floating with hand or power-driven equipment shall be started as soon as the screened surface has stiffened sufficiently, and shall be the minimum necessary to produce a surface that is free from screed marks and is uniform in color and texture.

c) Finish U3 (Troweled Finish):

This is a troweled finish used on surfaces where accurate alignment and evenness of surface are required for prevention of destructive effects of water action or as specified on the Drawings. Finish U3 shall be screened and floated as indicated for finishes U1 and U2, and shall consist of steel troweling the floated surface as soon as it has hardened sufficiently to prevent excess of fine material being drawn to the surface. Steel troweling shall be performed with firm pressure, such as will flatten the sandy texture of the floated surface and produce a dense, uniform surface, free from blemishes and trowel marks. Abrupt irregularities will not be permitted.

d) Finish for Slabs to Receive Topping:

This finish applies to structural slabs on which a separate topping will be placed. The finish shall be equal to finish U1 except that before the concrete has fully hardened, the surface shall be broomed so that the aggregate at the surface shall become exposed. Alternatively, these slabs may receive Finish U1 and subsequently roughened by chipping or scarifying if approved by the Engineer.

Unless otherwise shown on the Drawings or directed by the Engineer, all surfaces which would normally be horizontal and exposed to the weather, shall be sloped for drainage approximately 10 mm per one meter of width.

3017 Repair of Damaged or Defective Concrete

(1) General

Repair of damage or defective concrete shall be performed by skilled workmen only. No repair work shall be carried out until the Engineer has inspected the location of the proposed repair and has directed the method of repair.

The Contractor shall correct all imperfections on the concrete surface as necessary to produce surfaces that conform to the requirements specified in section 3016 "Finishing" .

Unless otherwise approved by the Engineer, repair of imperfections in formed concrete shall be completed within 24 hours after removal of forms. Concrete that is honeycombed, fractured, or otherwise defective, and concrete which, because of excessive surface depressions, shall be cut out and built up to bring the surface to the prescribed lines, shall be removed and replaced with dry pack mortar or concrete.

The Contractor shall correct abrupt or gradual irregularities which lie outside specified tolerances by rubbing with a carborundum stone or grinding where directed.

Materials and procedures specified to suit individual types of repair and to reinstate structural capacity of members may include use, as approved by the Engineer, of a proprietary non-ferrous non-shrink grout, epoxy or latex-based bonding agent, epoxy compound and cementitious grout, mortar and concrete. The Contractor shall, whenever possible, perform repair of defects while the concrete is still green. Curing interruptions shall be limited to the minimum time and area practicable.

The holes left by removal of pipes, tie-rods or other accessories shall be reamed with suitable toothed reamers before being cleaned and filled with dry pack as specified. All bulges or other projections on exposed surfaces shall be chipped and ground until a true smooth surface of matching color and texture is obtained.

(2) Dry pack

Dry pack material shall be placed and packed in thin layers. Each layer shall be solidly compacted. Dry pack shall be used for filling holes having at least one surface dimension less than the hole depth, for narrow slots cut for repair of cracks, for grout pipe recesses, and for tie-rod fastener recesses. Dry pack shall not be used for filling behind reinforcement or for filling holes that extend completely through a concrete section.

(3) Mortar

Mortar filling shall be placed under impact by use of a mortar gun, and may be used for repairing defects on surfaces designated to receive F1 and F2 finishes where the defects are

too wide for dry pack filling and too shallow for concrete filling and no deeper than the far side of the reinforcement that is nearest the surface.

(4) Concrete Placement

Concrete filling shall be used for holes extending entirely through concrete sections, for holes in which no reinforcement is encountered and which are greater in area than 0.1 square meters and deeper than 100 mm, and for holes in reinforced concrete which are greater in area than 0.15 square meters and which extend beyond reinforcement. Holes less than 0.15 square meters in reinforced concrete which extend beyond the reinforcement shall be enlarged to permit satisfactory filling of the hole with concrete.

Defective concrete shall be cut out to a depth of not less than 25 mm in sound concrete in all directions so that the edges of each hole are sharp-edged and undercut to provide a key, and the hole shall be cleaned, brushed and soaked 12 hours before being refilled. The fillings shall be tightly packed and completely bonded to the surface of the holes. The mix proportions of the filling materials shall be such to provide a strong, dense repair, which will avoid color variations in surfaces exposed to view. Where required by the Engineer, the Contractor shall supply white cement in sufficient amount, as determined by trial in the presence of the Engineer, which, when blended with normal cement, will produce a finish of similar appearance to the adjacent concrete. Non-shrink additives shall be used where a watertight joint is required. The surface of patches shall be smooth and flush with the surrounding concrete.

3018 Embedded Items in Concrete

All items, which are to be embedded in either primary or secondary concrete, shall be accurately set in place to conform to the required tolerance. All embedded items shall be thoroughly cleaned of rust, grease, paint, splashed mortar or other coatings that reduce bond. Prior to concrete placing, the Contractor shall satisfy himself that the parts are rigidly held and set to the required tolerance, and where so required by the Engineer, shall take formal delivery of the parts.

The methods of placement of concrete around the embedded parts shall be approved by the Engineer. The responsibility for maintaining the required tolerance shall lie with the Contractor. During concrete placing adjacent to embedded parts, vibrators shall not be allowed to touch any metal parts embedded in the concrete, and the concrete shall be placed in such a manner as not to disturb the embedded parts.

3019 Measurement and Payment

- (1) Measurement for payment of concrete cast in situ shall be made by volume in cubic meters of respective classes of concrete placed as computed from the dimensions shown on the Drawings.

Payment for concrete will be made at the unit price per cubic meter, which unit price shall include the cost for supply and storage of all necessary materials including cement, coarse and fine aggregates, water, admixtures and additives, form work, reinforcement bars and for testing all necessary materials, all measures necessary for batching and mixing of all materials, transportation of concrete, site preparation prior to pouring and casting, provision of joints, finishing, protection, curing and temperature control of concrete, supply and transportation of the specimens, and incidentals in order to complete the production and placement of concrete.

Payment of all necessary temporary works including dewatering for concrete works shall be included in the respective unit prices or prices.

Measurement and payment for other miscellaneous materials to be embedded in or installed on the concrete cast in situ shall be separately made as described in Section 3300 "Waterstop, Contraction Joint, Expansion Joint Filler and Dowel Bar".

SECTION 3100 FORM WORK

3101 General

(1) General

The fabrication, erection and removal of all the form works shall be carried out in order to construct the required concrete structures.

This Section covers the requirements for the design, materials, fabrication, erection and removal of formwork for concrete.

(2) Scope of Works

The Contractor's scope of form-works shall include services and furnishing of all design, labour, materials, equipment, consumables required for the execution of form-works.

The Works include, but are not limited to, the following:

- Form-work including all necessary supports
- Temporary protective measures as required
- Dewatering for concrete works
- Construction design as required

3102 Applicable Codes and Standards

The form-works shall conform to the following codes, standards and specifications or other equivalent codes and standards subject to approval of the Engineer, except as may be amended in this Specification:

The following standards and other publications are referred to in this section:

- ACI SP-4 Formwork for Concrete
- ACI 347 Recommended Practice for Concrete Formwork

3103 Materials and Workmanship

(1) Lumber

All materials used in the fabrication and erection of forms shall be of adequate strength and quality for their intended purpose, to meet the approval of the Engineer. Suitable local timbers shall be used.

Forms shall be of straight lumber, tongue and groove lumber, or plywood. Steel forms may be used only with the approval of the Engineer. All materials used in formwork shall be of a type

and strength sufficient to withstand the pressures due to the concreting, and deflection shall be within the tolerances specified.

Where finishes F2 or F3 specified, forms may be of plywood sheathing or lining, or tongue and groove lumber, and shall be approved by the Engineer.

(2) Form Ties

Internal ties shall be bolts and rods and they shall be straight and so arranged that when the forms are removed, no metal shall be left closer than 50 mm to any exposed surface for all finishes. Form ties shall not be fastened to reinforcement steel or embedded parts. Wire ties will not be permitted.

(3) Form Oil Coating

All form surfaces shall be thoroughly cleaned before erection and shall be coated with a non-staining mineral oil or lacquer. All excess oil shall be wiped off prior to concreting and no oil shall be permitted on the reinforcement steel or other embedded items. The use of all form coatings or lacquers shall be subject to the approval of the Engineer, and the Contractor shall be required to provide proof of compatibility between the product to be employed, the concrete itself, and any subsequent treatment that the formed surface is to receive. All form coatings shall prevent ingress of wood resins into the concrete surface.

(4) Workmanship

All forms shall be true to the required shape and size, shall conform to the established alignment and grade, and shall be of sufficient strength and rigidity to maintain their position and shape without displacement or deflection under the loads and operations incident to placing and vibrating the concrete. Formwork shall be so constructed to be readily removable without impact or damage to cast-in-place concrete.

Suitable and effective means shall be provided on all forms for holding adjacent edges and ends of panels and sections tightly together and in accurate alignment so as to prevent the formation of ridges, fins, offsets, or similar surface defects in the finished concrete. Forms shall be tight so as to prevent the loss of grout during placing and vibrating of the concrete between panels and subsequent lifts of concrete.

Any forms, which in the opinion of the Engineer are unsafe or inadequate in any respect, may, at any time, be rejected and the Contractor shall promptly remove the rejected forms from the Works and replace them.

3104 Design of Forms

The Contractor shall design all form-works and false-work. Notwithstanding any approval given to the Contractor by the Engineer, the Contractor shall remain responsible for the safety

and structural soundness of all form-work and false-work.

The Contractor shall submit the designs of all form-work and false-work to the Engineer for his approval. The Shop Drawings submitted for approval shall clearly indicate the dead and live loads assumed for the design, the maximum permissible speed of rise of concrete in the form, the dimensions of all structural members and the capacity of all ties, anchors and hangers.

3105 Construction of Forms

The construction of forms shall adhere to the Contractor's approved design and shall conform to the shapes, lines and dimensions of the structure as shown on the Shop Drawings. Failure or misalignment of the forms and any damage caused thereby shall be corrected by the Contractor.

At all unformed construction joints, wooden strips of a minimum size of 50 mm by 50 mm shall be secured to the inside of the forms at the location of each joint to ensure a uniform finish to the outside edges of any lift of concrete. The upper layer of concrete shall be worked up to and under these strips so as to provide smooth edges.

Unless otherwise shown on the Drawings, exterior external and interior arises shall be chamfered 20 mm.

3106 Inspection of Forms

Temporary openings shall be provided at the base of forms as necessary to facilitate cleaning and inspection. After inspection, these openings shall be closed in such manner that leakage during concreting is prevented and that the concrete surface finish is not impaired.

3107 Re-use of Forms

Forms shall be thoroughly cleaned and repaired to the satisfaction of the Engineer prior to re-use. Except where F1 finish is specified, metal patches shall not be allowed in the repair of forms.

3108 Removal of Formworks

Forms shall be removed as soon as practicable and the recommendations contained in ACI 347 shall be used as a general guides for determining the time for stripping. In all cases, forms shall not be removed until such removal is authorized by the Engineer.

Notwithstanding the recommendations of ACI 347, forms or sections containing waterstops shall not be removed within 24 hours after the placing of concrete.

The minimum period which shall elapse between the completion of concreting and the removal of forms shall be as follows:

Form For:	Minimum Period	Required Percentage of 28-days Strength
Vertical or near vertical face of mass concrete	24 hours	40 %
Vertical or near vertical face of columns, walls and large beams	2 days	40 %
Slab and Beams soffits (props left under)	7 days	70 %
Slabs (props left under)	3 days	50 %
Beam sides, walls and pier	2 days	40 %
Props under slabs	12 days	85 %
Props under beams	14 days	90 %
Props under cantilevers	28 days	100 %

3109 Measurement and Payment

Payment for formwork shall be included in the unit price of the plain or reinforced concrete in Pay Item SB-0210, SB-0211, PC-0324, PC-0325, PC-0326, PC-0327, PC-0328, PC-0329, PP-0779, PP-0780, PP-0781, DT-0811 and DT-0812 which shall include the supply and storage of all materials and for all measures necessary for preparation, fabrication, transportation, placing and erection, supporting, scaffolding, removal, cleaning and incidentals.

Separate payment shall not be made for respective kinds of formwork to complete the relevant finishing as specified in Section 3016 "Finishing" .

SECTION 3200 REINFORCEMENT BAR

3201 General

(1) General

The furnishing, cutting, bending and erection of all the reinforcement bars shall be carried out in order to construct the required concrete structures. This section covers the material requirements, bending and erection of the reinforcement bars to be used in the concrete.

(2) Scope of Works

The Contractor's scope of reinforcement bar works shall include services and furnishing of all design, labour, materials, equipment, consumables required for the execution of reinforcement bar works.

The Works include, but are not limited to, the following:

- Bar-placing drawings and bar-bending diagrams
- Protection for reinforcement bars
- Fabrication of reinforcement bar
- Erection of reinforcement bar
- Temporary protective measures as required
- Dewatering for concrete works

(3) Bar-placing Drawings and Bar-bending Diagrams

The size and spacing of the reinforcement bar shall be as shown on the Shop Drawings. The Contractor shall prepare and submit to the Engineer, for approval, reinforcement detail drawings for all structures, including bar-placing drawings, bar bending diagrams and bar lists before commencement of bar cutting and bending.

Bar-placing drawings and bar-bending diagrams to be prepared by the Contractor shall conform in general to the concrete lifts shown on the Drawings. In the event that the Contractor requests changes in lift heights and the Engineer approves such changes, the Contractor shall revise or replace bar-placing drawings and bar-bending diagrams to suit the changed lift.

Such bar-bending diagrams and bar-placing drawings revised by the Contractor shall be submitted to the Engineer for his approval prior to concreting at the portion of the changed lift.

3202 Applicable Codes and Standards

The reinforcement bar works shall conform to the following codes, standards and specifications

or other equivalent codes and standards subject to approval of the Engineer, except as may be amended in this Specification:

The following standards are referred to in this section:

ACI	318	Building Code Requirements for Reinforced Concrete
ASTM	A 497	Standard Specification for Steel Welded Wire Fabric, Deformed, for Concrete Reinforcement
ASTM	A 615	Standard Specification for Deformed and Plain Billet-Steel Bars for Concrete Reinforcement

3203 Materials and Workmanship

(1) Materials

Reinforcement bars shall be of deformed bars and shall conform to ASTM A 615. Minimum yield strength of the bars shall be as follows:

Grade 37	Fy=2,300kg/cm ²	(Normal mild steel for Round bar)
Grade 52	Fy=3,600kg/cm ²	(High grade steel for Deformed bar)

Tie wire shall be heavy black annealed iron wire. Preformed clips or attachments shall be of proper design and strength so that reinforcement bars are rigidly supported in position.

(2) Workmanship

All workmanship shall be of the best quality in each respective category of the Works. Except where otherwise stated, or approved by the Engineer, all materials used in the Works shall be of the best quality, in the respective kinds specified or described in the Specifications, Drawings and Bill of Quantities, and shall comply wherever possible with the current issue of the reference Standards or other equivalent approved national standards, subject to the approval of the Engineer.

3204 Protection

Reinforcement bars shall be stacked for storage purposes clear of the ground such that it will not become submerged in standing water.

Reinforcement bar shall be protected at all times from damage. When placing in the works, it shall be free from dirt, detrimental scale, paint, laitance, mortar, oil or other foreign substance.

Reinforcement bar embedded or partially embedded in the concrete shall remain completely undisturbed for a minimum period of 24 hours or longer if the Engineer so directs, after the concrete placement has been completed.

3205 Fabrication

Reinforcement bar shall be cut and bent cold, unless otherwise permitted by the Engineer, to the dimensions and shapes as shown on the approved Shop Drawings with equipment and methods approved by the Engineer. The reinforcement bar partially embedded in the concrete shall not be field bent.

All bars shall be cut from stock length. Bends and hooks shall be made in accordance with the requirements of ACI 318. The reinforcement bar having cracks or splits on the bends shall be rejected.

Reinforcement bar shall not be straightened or bent again once having been bent, except otherwise approved by the Engineer.

Fabricated reinforcements shall be properly tagged for easy identification.

3206 Erection

Reinforcements shall be accurately erected in accordance with the approved Shop Drawings and shall be securely wire-tied at each intersection. Metal or concrete chairs and metal spreaders of approved types shall be used where necessary for support or spacing of bars. The reinforcements shall be erected within the limit of the following tolerances:

Concrete cover:	-3 mm to +6 mm
Longitudinal location of bends:	±25 mm
End of bar:	±25 mm

All reinforcement bars shall be furnished in the full lengths shown on the approved Shop Drawings. Splicing of bars will not be permitted without the prior written consent of the Engineer. The splicing shall be by overlapping, as indicated on the Drawings. Splices may also be made by the use of approved couplings or by special welding techniques as approved by the Engineer.

Concrete protection for reinforcement shall conform to the requirements of ACI 318, unless otherwise shown on the Drawings.

The following concrete covering for main reinforcement shall be provided, unless noted otherwise:

- 50 mm for concrete cast against and permanently exposed to earth (foundations)
- 15 mm for slab and walls (above G.L.)
- 25 mm for beams and columns (above G.L.)

3207 Measurement and Payment

Payment for reinforcement bar shall be included in the unit price of the reinforced concrete in Pay Item SB-0211, PC-0325, PC-0326, PC-0327, PC-0328, PC-0329, PP-0780, PP-0781 and DT-0812 which shall include the cost for supply, bending, cutting and erection of reinforcement bar, provision and using of tie wire, metal and concrete support, spacers and other fixing devices, coupling or welding, and other incidentals.