9.1.2 CONCRETE WORKS AND PILING

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9.1. 2.1 CONCRETE WORKS

9.1.2.1.1 Scope of Work

The Contractor shall provide all labour, equipment, materials and incidentals required to furnish mix, transport, and place all ready-mixed and/or insitu concrete and install miscellaneous related items including forms, sleeves, anchor bolts, inserts and embedded items.

Non of the requirements of this specification shall relieve the Contractor of his responsibility to produce in the Works only sound, well compacted concrete free from voids and cracks.

9.1.2.1.2 General Provisions

Concrete shall be composed of Portland cement, fine aggregate, coarse aggregate, water and admixtures, as specified for the work, except as otherwise authorised in writing by the Engineer. Ready mix concrete shall be permitted, provided it can be placed within the time requirements specified, and complies with all of the provisions herein specified.

Reinforced concrete and workmanship shall conform to

BS 8110	Framed building structures
BS 8007	Water Retaining Structures
BS 8004	Foundations
BS 5328	Specifying Concrete including Ready-mixed Concrete

All testing and inspection services required, will be done at no additional cost to the Employer at the field laboratory provided by the Contractor as specified in Chapter 1.6, or as instructed by the Engineer. Methods of testing will comply in detail with the applicable ASTM "Methods of Test."

9.1.2.1.3 Submittals

Samples of constituents and of concrete as placed will be subjected to laboratory tests. The Contractor will submit samples as directed by the Engineer. All materials incorporated in the Works shall conform to the approved samples.

The Contractor shall design the concrete mixes for all classes of concrete as defined in BS 8110 Clause 6.3 and submit his proposal together with the test results of the strength of all classes of the concrete mix design for the approval of the Engineer. The design of the concrete mixes and the concrete strength test shall be made in the field laboratory in the presence of the Engineer's representative. The Contractor is responsible for all expenses incurred in this process.

The use of ready-mixed concrete in any part of the Work shall require the Engineer's written approval. The contractor shall satisfy the Engineer as to the sampling, trial mixing, testing and quality of concrete of various grades shall apply to ready-mixed concrete which shall be made and delivered in accordance with BS 5328.

Every additional facility, including transport, which the Engineer or persons authorised by him may require for the supervision and inspection of batching mixing and transporting to Site of ready-mixed concrete. Shall be provided by the Contractor at no extra cost to the client.

Prior to any major concreting as instructed by the Engineer, the Contractor shall submit a method statement furnishing all the relevant details including the plants he intends to use, for the approval of the Engineer.

9.1.2.1.4 Quality

The Contractor shall furnish and place concrete as required by these Specifications. The concrete to be produced and placed shall be of the highest quality and uniformity. The Contractor, in all phases of his operations, will be subject to strict inspection to provide concrete construction of excellent quality. Emphasis will be placed on the uniformity of the concrete aggregate, water-cement ratio, consistency, air content, curing and temperature control of the concrete at the time of placement in the forms.

Where screen sizes for concrete aggregates are shown in United States of America standard sizes, the Contractor may utilise standard screens having metric dimensions closely approximating these sizes as approved by the Engineer.

Consistency of the concrete as measured by the ASTM C143 "Slump of Portland Cement Concrete", shall be as shown in Table 9.1.2.1.

TABLE 9.1.2.1

Portion of Structure	Slump in mm.	Recommended Range
Pavement and slabs on ground	50	25 - 75
Plain footings, gravity walls, slabs and beams	50	25 - 75
Heavily reinforced foundations, walls and footings, cast in situ piles (concreting in dry condition)	75	50 - 100
Thin reinforced walls and columns	75	50 - 100
Concreting under water	150	125 - 180

Concrete shall be of such consistency and mix composition that it can be readily worked into the corners and angles of the forms and around the reinforcement, inserts, embedded items and wall castings without permitting materials to segregate or free water to collect on the surface, due consideration being given to the methods of placing and compacting.

No excessively wet concrete will be permitted and, if at any time, concrete of consistency beyond the limits of Table 9.1.2.1 is delivered to the job, the Engineer may reject the concrete. No additional water shall be added at any time (eg. While in transit) except that established for the design. Failure to comply with this requirement shall be justification for rejecting the concrete.

The actual acceptance of aggregates and mix design to produce concrete conforming to the specific requirements shall be determined by means of prior laboratory tests made with the

constituents to be used on the work to achieve the specified objectives of strength and of appearance as defined in 9.1.2.1.12. The ratio between the fine and course aggregates shall be higher than 1: 1.5. The proportion of constituents, and mix shall be in accordance with;

BS 5328 & BS 8110 : Part I - 1985 for framed buildings
BS 8007 - 1987 for water retaining structures

Thirty days in advance of placing concrete, the Contractor should produce the method statement and discuss with the Engineer the proposed time, sources of materials and concrete mixes which he proposes to use. He shall furnish samples of aggregate and cement for testing, deliver and test them at his own cost, and shall permit ample time for the laboratory to develop a proposed design mix or to modify the design of the mix within the limits of these specifications to achieve the finished results.

The limiting strengths, water-cement ratios and cement contents, as shown in Table 9.1.2.2 shall apply unless otherwise noted on the drawings.

TABLE 9.1. 2.2

Class of Concrete	Minimum Characteristics Cube Strength at 28 day (N/sq.mm)	Maximum Water: Cement Ratio	Minimum Cement Content (kg/cu. M)	Maximum Cement Content (kg/cum)
C40	40	0.55	325	350
C35 A	35	0.55	325	350
C25	25	0.55	230	350
C20	20	0.55	180	350
C15	15	0.55	180	350

These cement contents apply to "controlled" concrete subject to specific inspection.

If, during the progress of the work, the Contractor desires to use materials other than those approved originally, or if the materials from the sources originally approved change in characteristics, the Contractor shall, at his expense, carry out new acceptance tests of aggregates to establish new basic mixes and obtaining the approval of the Engineer prior to use. Objectionable changes in colour of the structures shall not result from these modifications.

9.1.2.1.5 Acceptance Tests

Conformity of aggregates to this specification, and the actual proportions of cement, aggregates, and water necessary to produce concrete conforming to the requirements set forth in Tables 9.1.2.1 and 9.1.2.2 shall be determined by tests made with representative samples of the materials to be used for the work. Preparation of samples and tests shall be made at the field laboratory in the presence of the Engineer's designated representative. Representative samples shall be furnished by the Contractor at his own cost.

Cement shall be subject to testing to determine that it conforms to the requirements of this specification. Methods of testing shall conform to the appropriate specification, but the place, time, frequency, and method of sampling shall be determined by the Engineer in accordance with the particular need.

Samples of fine and coarse aggregates shall be furnished for examination and testing at least three weeks before the Contractor proposes to use them in the work.

Water content of the concrete shall be based on a curve showing the relation between water content and 7 and 28 day compressive strengths of concrete made using the proposed materials. The curves shall be determined by four or more points, representing an average value of at least three test specimens at each age, and shall have a range of values sufficient to yield the desired data, including all the compressive strengths shown on the drawings, without extrapolation. The water content of the concrete to be used, as determined from the curve, shall correspond to the test strengths of the laboratory trial mixes as shown in Table 9.1.2.3.

TABLE 9.1.2.3

Concrete Cube Strength, N/sq. mm		
	Minimum Lab. Strength	
Strength	7 days	28 days
C40	28	40
C35A	23.2	35
C25	16.5	25
C20	13.2	20

In no case, shall the resulting mix conflict with the values for maximum water-cement ratios and minimum cement contents as specified in Table 9.1.2.2.

9.1.2.1.6 Materials

(1) Cement

Cement shall be Portland cement to BS12. Air entraining cements shall not be used. Cement brands shall be subject to approval of the Engineer. Rapid hardening cement shall not be used without the approval of the Engineer.

(2) Coarse aggregate shall be crushed granite to BS 882.

(3) Fine Aggregate

Fine aggregate shall be natural river sand to BS 882 Marine aggregates shall not be used.

Aggregates shall not contain any materials that are deleteriously reactive with the alkalis in the cement.

Fine aggregate shall conform to the following requirements:

US Sieve No.	Percentage Retained	Percentage Passing
4	0 - 5	95 - 100
16	25 - 40	60 - 75
50	70 - 87	13 - 30
100	93 - 97	3 - 7
Requirements (see ASTM C33)		
Fineness Modulus	2.30 - 3.00	
Organic	See ASTM C40	
Silt	2.0 Percent maximum	
Mortar Strength	95 Percent minimum compression ratio	
Soundness	8 Percent maximum loss, Magnesium Sulphate, 5 cycles	

Materials from approved quarries shall be tested periodically for the following characteristic

1. Gradation
2. Specific Gravity
3. Organic Content

(4) Coarse Aggregate

Coarse aggregate shall consist of well graded granite conforming to the requirements of BS 812 and shall not contain any materials that are deleteriously reactive with the alkalis in the cement.

The following designated sizes* of aggregate shall be the maximum employed in concrete.

40 mm for plain concrete
20 mm for reinforced sections

* Note: The "designated size" and the corresponding gradations shown represent the end or combined gradation of the coarse aggregate to be used in the final concrete.

Materials from approved quarries shall be tested periodically for the following characteristic

1. Gradation
2. Specific gravity
3. Los Angeles abrasion test
4. Magnesium Sulphate soundness test

(5) Water

Water shall be clean and free from injurious amounts of oils, acid, alkali, organic matter, or other deleterious substances and shall comply with the requirements of BS 3148. Potable tap water will normally fulfil these requirements.

When subjected to the mortar strength test described in ASTM C87, "Effect of Organic Impurities in Fine Aggregate on Strength of Mortar", the 28-day strength of mortar specimens made

with the water under examination and normal Portland cement shall be not less than the strength of similar specimens made with distilled water.

(6) Admixtures:

Unless approved by the Engineer in writing , no admixtures shall be used.

Admixtures shall conform to ASTM C 494 or BS 5075 – Part 1. The Contractor may also be required to use a retarding, or water reducing and retarding admixture conforming to ASTM C494 and as approved by the Engineer, under conditions contributing to early set of concrete, or when the temperature of concrete is 30°C or above, or when the time between introduction of cement to the aggregate and placing of concrete exceeds 45 minutes. If admixtures are used, it will be at the Contractor's option and at no additional cost to the Employer.

Compatibility of all proposed admixtures shall be tested for compatibility with proposed cement and aggregate in accordance with ASTM C494.

The amounts and types of additives used shall be as directed or approved by the Engineer and may be varied by him according to the location of the work or for other reasons.

(7) Storage of Materials

(i) Aggregates

Aggregates shall be separately stored so as not to become mixed with one another and so as to prevent contamination. Materials of similar grading but from different sources or different types, shall not be stored together unless approved.

Aggregate stockpiles shall be provided with impervious beds laid to facilitate drainage, and any adjacent roads shall be so formed as to prevent drainage to the stockpiles and bin loading areas.

Aggregate stockpiles shall be covered by a structure or structures which shall remain in position throughout the Contract and this cover shall effectively protect the stockpiles from rain. For each size of aggregate, separate duplicate stockpiles shall be provided and worked on alternate days to allow all aggregates to drain for at least 16 hours prior to use.

Aggregate in stockpiles shall not be contaminated or crushed by trucks, bulldozers, or other plant equipment.

The Contractor shall avoid the build-up of fine material at the bottom of the stockpiles. Should such build-up occur, the layer which contains an excess of fine material shall be removed as directed by the Engineer.

(ii) Cement

To protect cement from premature hydration after delivery, bulk silos should be waterproof and internal condensation should be minimised. Paper bags should be stored clear of the ground, not more than eight bags high and protected by a waterproof structure. As significant strength losses begin after 4 weeks to 6 weeks of storage in bags in normal conditions, and considerably sooner under adverse weather conditions or high humidity, deliveries should be controlled and used in order of receipt.

Different types or brands of cement shall be stored separately.

(iii) Reinforcement

Reinforcement shall be stored on site either in racks or on a hard impermeable base so that it remains straight and free from contamination. Any reinforcement which is likely to remain in storage for a long period shall be protected from the weather so as to avoid corrosion and pitting. If required by the Engineer, corroded reinforcement shall be removed from site.

9.1.2.1.7 Measuring Materials

Materials shall be measured by weighing except when otherwise authorised by the Engineer. The apparatus for weighing aggregates and cement shall be designed and constructed for this purpose, and shall be regularly calibrated. Each size of aggregate and cement shall be weighed separately. The accuracy of all weighing devices shall be such that the successive quantities can be measured to within one percent of the desired amount.

Cement in standard packages (sacks) need not be weighed, but bulk cement shall be weighed.

The mixing water shall be measured by volume or by weight. The water measuring device shall control the volume or weight accurately to 1/2 percent. All measuring devices shall be subject to approval by the Engineer.

Admixtures shall be dispensed either manually with the use of calibrated containers or by an approved automatic dispenser designed by the manufacturer of the specific admixture.

9.1.2.1.8 Mixing

Concrete shall be produced by equipment acceptable to the Engineer. Hand mixing will not be allowed. Adding water in controlled amounts during the mixing cycle shall be done only with the express approval of, and under the direction of the Engineer.

Concrete shall be mixed until there is a uniform distribution of the materials and shall be discharged completely from the mixer before the mixer is recharged.

Site mixers shall be equipped with suitable charging hoppers and a water storage and water measuring device, so constructed that some water will enter in advance of the cement and aggregate when the mixer is being charged with a batch. The mixing water measuring device shall have its adjustment locked in order to prevent tampering by unauthorised persons.

The loss of materials during charging will not be permitted. At regular intervals the mixers shall be cleaned of any hardened concrete which may have formed on the inside of the drum.

Ready-mixed or transit-mixed concrete shall be transported to the site in watertight agitator or mixer trucks loaded not in excess of the rated capacities for the respective conditions as stated on the name plate. Central mixed concrete shall be plant-mixed a minimum of 1.5 minutes per batch and then shall be truck-mixed or agitated a minimum of 8 minutes. Agitation shall begin immediately after the premixed concrete is placed in the truck and shall continue without interruption until discharged. Transit-mixed concrete shall be mixed at mixing speed for at least 10 minutes immediately after charging the truck, followed by agitation without interruption until discharged.

All central plant, rolling stock, equipment, and methods shall conform to ACI Standard 214, "Recommended Practice for Measuring, Mixing and Placing Concrete", and ASTM C94, "Ready-Mixed Concrete".

The total elapsed time between the intermingling of the aggregates and cement and the start of mixing shall not exceed 30 minutes.

Ready-Mixed Concrete

1. The use of ready-mixed concrete in any part of the Work shall require the Engineer's written approval.

2. Contractor shall satisfy the Engineer on the following:

   a. Materials used in ready-mixed concrete comply with the Specification in all respects.
   b. Manufacturing and delivery resources of the proposed supplier are adequate to ensure proper and timely completion.

3. The specified requirements as to the sampling, trial mixing, testing and quality of concrete of various grates shall apply equally to ready-mixed concrete.

4. Every additional facility, including transport, which the Engineer or persons authorised by him may require for the supervision and inspection of the batching, mixing, testing and transporting to Site of ready-mixed concrete shall be provided by the Contractor at no extra cost.

5. Ready-mixed concrete shall be supplied from an off-site commercial ready-mix plant approved by Engineer.

   Each load shall be accompanied by a bond weighmaster's certificate listing:

   1. Type and strength of the mix being delivered
   2. Quantity of each concrete ingredient.
   3. Admixture quantity.
   4. Water content.
   5. Slump.
   6. Time of loading and departure from ready-mix plant.

6. Unless approved otherwise in advance of batching all concrete of single design mix for any one day's pour shall be from a single batch plant of a single supplier.

   a. Ready-mix concrete shall conform to BS 5328.
   b. Transit mixers equipped with automatic devices for recording the number of revolutions of the drum shall be used.
   c. No water shall be added during transporting to site or at the site.
   d. Each mixer truck shall arrive at the job site with its water container full.
      In the event that water container is not full of concrete tests give a greater slump than acceptable, the load shall be rejected.

7. Shade temperature and concrete temperature shall be recorded at the point of discharge of the mixer and at placement for each load of concrete delivered to site.

8. Maximum and minimum temperatures and wet bulb temperatures shall be recorded daily.

9. Perform slump tests in accordance with BS 1881at the site of pour for each load delivered to site.

Concrete installation shall proceed only following satisfactory verification of slump test results.

9.1.2.1.9 Transporting

When the mixture is very far from the placement location slump, temperature and the time shall be recorded frequently on each and every truck road transporting concrete at the mixture and the point of the placement.

When a truck mixer or agitator is used for transporting concrete to the delivery point, discharge and placing shall be completed within 1.0 hour, or before 250 revolutions of the drum or blades, whichever comes first, after the introduction of the cement to the aggregates. Under conditions contributing to early initial set of the concrete, or when the temperature of the concrete is 32°C or above, a time less than 45 minutes will be required.

When non-agitating hauling equipment is used for transporting concrete to the delivery point, discharge and placing shall be completed within 0.5 hours after the addition of cement to the aggregates under normal circumstances and not more than 15 minutes under conditions contributing to easy initial set of the concrete, or when the temperature of the concrete is 30°C or above.

If the above time conditions as to discharge and placing of concrete after introduction of cement cannot be met, the Contractor may be required to use a retarding or a water reducing and retarding admixture. The use of a retarding admixture will be according to ASTM C494 and must be approved by the Engineer, and no extra cost to the Employer.

The re-tempering of concrete or mortar which has partially hardened and mixing with or without additional cement, aggregate, or water, will not be permitted.

The Contractor shall dispatch trucks from the batching plant so that they shall arrive at the site of the work just before the concrete is required, thus avoiding excessive mixing of concrete while waiting for placing successive layers of concrete in the forms.

Precautions shall be taken in hot weather to prevent loss of slump. Mixer drums shall, when possible, be shaded, lagged and materials shall be kept as cool as possible.

9.1.2.1.10 Field Tests

Sets of three field control test specimens will be selected at random for each structure by the Engineer during the progress of the work, in conformity with ASTM C31, "Making and Curing Concrete Compressive and Flexural Strength Tests Specimens in the Field". The total number of specimens taken on the project may average one set per 100 cubic meters per class of concrete and in general not less than one set of specimens will be taken on any day that concrete is placed. The Contractor shall be responsible for the expenses in taking and transporting the concrete specimens to the laboratory.

The results of the testing shall be conforming to the recommendations given in BS 8007 : 1987 "British Standard Code of Practice for design of concrete structures for retaining acquires liquids."

When it appears that the laboratory cured specimens will fail to conform to the requirements for strength, the Engineer shall have the right to order changes in the concrete sufficient to increase the strength to meet these requirements. The strengths of any specimens cured on the job are intended to indicate the adequacy of protection and curing of the concrete and may be used to determine as to when the forms may be stripped, shoring removed, or the structure placed in service. When in the opinion of the Engineer the strength of the job cured specimens are excessively below those of the laboratory cured specimens, the Contractor may be required to improve the procedures for protecting and curing concrete.

The Contractor shall provide for all costs in the making of such tests including allowing free access to the work for the selection of samples, providing moist storage facilities for specimens, affording protection of the specimens against injury or loss through his operations, and furnishing material and labour required for the purpose of taking and testing samples.

Slump tests shall be made in the field by the Contractor as and when instructed by the Engineer in the presence of the Engineer's representatives.

9.1.2.1.11 Inspection and Control

The preparation of forms, placing of reinforcing steel, embodiment items, conduits, pipes, and sleeves, batch mixing, transportation, placing and curing of concrete shall be subject to the inspection of the Engineer, as well as the testing in the laboratory.

9.1.2.1.12 Concrete Appearance

Concrete for every part of the work shall be a homogeneous structure which, when hardened, will have the required strength, durability and appearance. Form work, mixtures and workmanship shall be such that concrete surfaces, when exposed, will require no finishing.

When concrete forms are stripped, the concrete surfaces when viewed in good light from 6 meters away shall be pleasing in appearance, and shall show no visible defects.

9.1.2.1.13 Forms

Forms shall be used for all concrete work, including footings. Forms shall be so constructed and placed that the resulting concrete will be of the shape, lines, dimensions, appearance, and to the elevations indicated on the drawings and conforming to ACI347, "Recommended Practice for Form work". Whenever so instructed by the Engineer, the Contractor shall submit shop drawings and calculations for form work and temporary works at no additional cost to the Employer.

Forms of all cast-in-place concrete shall be made of wood, metal, or other approved material. Wood forms shall be constructed of sound lumber or plywood of suitable dimensions free from knotholes and loose knots. Plywood shall be sanded smooth and fitted with tight joints between panels. Metal forms shall be of an approved type for the class of work involved and of the thickness and design required for rigid construction. All exposed concrete shall be formed with metal or plywood forms.

Edges of all form panels in contact with concrete shall be flush within 0.8 mm and forms for plane surfaces shall be such that the concrete will be plane within 2 mm each 4 meters. Forms shall be tight to prevent the passage of mortar, water or grout. Forms shall generally be constructed as that the finished concrete conforms to ACI 117 "Standard Tolerance for Concrete Constructions and Materials".

Moulding or bevels shall be placed to produce a 20 mm chamfer on all exposed projecting corners, unless otherwise noted on the drawings. Similarly chamfer strips shall be provided at horizontal and vertical extremities of all wall placements to produce "clean" separations between successive placements as shown on the drawings.

Forms shall be sufficiently rigid to prevent displacement or sagging between supports, under all conditions, and shall be so constructed that the concrete will not be damaged by their removal. The Contractor shall be entirely responsible for their adequacy.

Forms shall be oiled before reinforcement is placed with an approved non-staining oil or liquid form coating not having a paraffin base.

Before form materials are reused, all surfaces that have been in contact with concrete shall be thoroughly cleaned, all damaged places repaired, all projecting nails withdrawn, and all intrusions or protrusions smoothed.

Form ties encased in concrete shall be designed so that after removal of the protecting part, no metal shall be within 25 mm of the face of the concrete. That part of the tie to be removed shall be at least 12 mm in diameter or be provided with a wood or metal cone at least 12 mm in diameter and 25 mm long. Form ties in concrete exposed to view shall be of the cone-washer type. Through-bolts or common wire shall not be used for form ties.

Before placing concrete, the Engineer may inspect the forms, as to condition, cleanliness, joint preparation, and ascertain that all reinforcement and embedded items are adequately supported in the proper location. This inspection shall not relieve the Contractor of his responsibility for the adequacy of the forms or for the completeness and accuracy of embedded items.

Holes and seams in the forms shall be such that water and mortar will not escape. Forms in the vicinity of joints shall be re-tightened just prior to placing the next lift. During concreting, the Contractor shall maintain the forms tight and in position. Any necessary adjustment shall be made immediately.

9.1.2.1.14 Casting Sequences, Placing and Compacting

(i) Ground Reservoir

Concreting of large floors walls and roof slabs in reservoirs where prevention of shrinkage cracking is essential shall be cast in an order that gives free edges in two direction as right angles as far as possible. For floor slabs, place concrete between expansion joints or construction joints in one continuos operation. For walls, place concrete in one continuos pour without construction joints. The new panels shall not be cast until the adjacent panels are at least one week old after casting. Each wall panel shall be cast within one week of the casting of the kicker to which it is monolithic. Subsequent lifts within the panel shall be cast when the previous lift not more than one week old. There is no restriction on the timing of the casting of adjacent wall panels separated by expansion joints.

(ii) Tower Reservoirs

The raft foundation may be cast in one operation. The RC circular wall supporting the tank may be slip formed with horizontal construction joints at intervals not more than 2.5 m. The conical floor, and the domed bottom can be divided in to equal segments of length/breadth is not more than 5.0 m. Casting shall be in an order that gives free edges in two direction as right angles as far as possible. The outer vertical wall & beams can be cast in a similar manner. The domed roof may be

cast in one operation. The annular shaft within the tank shall be cast in complete rings in lifts not more than 2.5 m in height.

(iii) Concreting Programme

The Contractor shall submit for the approval of the Engineer a complete concreting programme, showing the timing of concreting of individual pours with dates, before commencement of the work.

(iv) Placing

Exterior concrete slabs shall be pitched or crowned to prevent ponding and facilitate drainage. Unless otherwise permitted, the work shall be so executed that a section begun on any day shall be completed in daylight of the same day.

Transport of concrete from mixer to place of final deposit shall be done as rapidly as practical by methods which prevent the separation of ingredients and displacement of reinforcement, and which avoid re-handling. No partially hardened concrete shall be deposited.

Concrete shall be transported from the mixer trucks by skips, barrows, buckets on cranes, chutes, or conveyor belts. All equipment used to transport concrete shall be clean and free of debris and contaminants. In selecting the method or methods used for transport, consideration shall be given to the effects of the method on the properties of the concrete so as not to result in inferior concrete caused by segregation produced during transport.

Bottom opening skips or buckets shall not be used for transporting over long distances because of the consolidation, bleeding or loss of slump which may result. Buckets or skips shall be capable of free discharge of low slump concrete, with gate mechanisms which permit full control over the discharge with no appreciable segregation.

Chutes shall be U-shaped and of such size as to ensure a continuous flow in the chute. Flat chutes shall not be used. Chutes shall be metal or metal lined and sections shall have approximately equal slopes. The slope shall be not less than 25 degrees and not greater than 45 degrees and shall be such as not to cause segregation of the ingredients. When the placing operation is intermittent, the chute shall discharge into a hopper. Concrete shall be deposited at or near its final position in the placement. Chutes shall be provided with a baffle and down pipe at the discharge end to provide a vertical drop thus minimising segregation.

Free fall of concrete shall be limited to 500 mm. In case this free fall cannot be maintained by the delivery hose of the concrete pump or the skip bucket, tremie pipe of diameter less than 100 mm shall be used. As far as practicable, pipe shall be kept full of concrete during placing and their lower end shall be kept buried in the newly placed concrete. After initial set of the concrete, the forms shall not be jarred and no strain shall be placed on the ends of reinforcement bars which project.

Chutes, hoppers, spouts, and other equipment shall be thoroughly cleaned before and after each use. The water and debris shall not be discharged inside the form.

Precautions shall be taken to protect concrete during transport in hot weather. The elapsed time between mixing and placing shall be kept to a minimum and where possible, trucks waiting to discharge shall be kept in the shade.

"Cold Joints" are to be avoided, but if they occur, are to be treated as bonded construction joints by using epoxy to the approval of the Engineer. The application of the epoxy shall be as recommended by the manufacturer.

At construction joints the surfaces of the concrete already placed shall be thoroughly cleaned of foreign materials and laitence, and weak concrete shall be roughened with suitable tools to expose a fresh face. At least two hours before and again shortly before the new concrete is deposited, the joints shall be saturated with water. After glistening water disappears, the joints shall be given a thorough coating of cement grout mixed to the consistency of a very heavy paste. The surfaces shall receive a coating at least 0.5 cm thick, well scrubbed in by means of stiff bristle brushes wherever possible. New concrete shall be deposited before the cement grout dries.

Deposit concrete so as to maintain a plastic surface approximately horizontal until the completion of the unit. Vertical lifts shall not exceed 600 mm and preferably 450 mm. Vibrators should be inserted at least 15 cm into the preceding layer if there is such.

Where the placement consists of several layers, each layer should be placed while the preceding layer is still plastic in order to avoid cold joints. If the under laying layer has stiffened just beyond the point where it can be penetrated by the vibrator, bond can still be obtained by thoroughly and systematically vibrating the new concrete into contact with the old; however, an unavoidable joint line will show on the surface when the form is removed.

In thin sections such as wall panels concrete shall be placed using suitable hoppers, spouts with restricted outlets, or otherwise, as required or approved by the Engineer.

(v) Compacting

Concrete, during and immediately after depositing, shall be thoroughly compacted by means of suitable tools. Internal type mechanical vibrators shall be employed to produce the required quality of finish. Vibration shall be done by experienced operators under close supervision and shall be continued sufficiently to produce homogeneity and optimum consolidation without permitting segregation of the solid constituents. All vibrators shall be supplemented by proper wooden spade puddling approximately adjacent to the forms to remove included bubbles and honeycomb. All vibrators shall operate at not less than 10,000 vibrations per minute (170 Hz) and be of adequate capacity. At least one vibrator shall be available for every 8 cubic meters of concrete placed per hour. In addition, one spare vibrator in operating condition shall be on the site. Particular care shall be taken in the regions of water-stops.

Vibration shall be applied at the point of deposit and in the area of freshly deposited concrete. The vibrators shall be inserted and withdrawn out of the concrete slowly. No poker holes shall be left after withdrawal of vibrator. 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 be continued at any one point to the extent that localised areas of grout are formed.

Application of vibrators shall be at points uniformly spaced and not farther 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. 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.

Concrete slabs on the ground shall be well tamped into place. Foundation material shall be wetted, tamped, vibrated, and rolled until thoroughly compacted prior to placing concrete.

Concrete shall be deposited continuously in layers of such thickness that no concrete will be deposited on concrete which has hardened sufficiently to cause the formation of seams and planes of

weakness within the section. If a section cannot be placed continuously, construction joints may be located at points as provided for in the drawings or as approved by the Engineer.

9.1.2.1.15 Curing and Protection

The Contractor shall protect all concrete work against injury from the elements and defacement of any nature during construction operations.

All concrete, particularly exposed surfaces, shall be treated immediately after concreting or cement finishing is completed, and shall be provided with continuous moist curing for at least 7 days, regardless of the ambient air temperature. Walls and vertical surfaces may be covered with continuously saturated burlap, or by other approved means; horizontal surfaces, slabs, and other items shall be ponded to a depth of 1.2 cm and kept continuously wet with the use of sprinklers.

Finished surfaces and slabs shall be protected from the direct rays of the sun to prevent checking and crazing.

9.1.2.1.16(a)Placing Concrete in Hot Weather

Care shall be taken to prevent rapid drying and plastic cracking of newly placed concrete. When the ambient temperature in the forms is more than 32°C or when so directed, the temperature of the concrete as placed shall not exceed 32°C. The Contractor shall make precautions to reduce the temperature of concrete by mechanical refrigeration using ice as a part of mixing water or alternative method acceptable to the Engineer. The fresh concrete shall be shaded as soon as possible after placing, and curing by use of fog spray shall be started as soon as the surface of fresh concrete is sufficiently hard. Concrete placement will not be permitted if, in the opinion of the Engineer, the Contractor does not have proper facilities available for placing, curing and finishing the concrete in accordance with these specifications. The Contractor shall comply with the recommendations of ACI 305, "Hot Weather Concreting".

9.1.2.1.16 (b)Placing of Concrete During Rain

Concreting shall not start during time of heavy rainfall. When directed by the Engineer to continue placing concrete during times of rainfall, the Contractor shall protect the work by covering to prevent water collecting in pools or washing the concrete surface. Only sufficient area shall be uncovered at a time as will permit the deposition of one load of concrete.

9.1.2.1.17 Removal of Forms

The period of time elapsing between the placing of concrete and the striking of form work shall be approved by the Engineer after consideration of the loads likely to be imposed on the concrete, and shall in no case be less than the period shown below:

Type of formwork	Minimum period before stripping (times are exclusive of the day of concrete placement)
Props to beams and slabs	14
Beams and slabs without props	14
Beam and slab Soffits (props left under but not re-propping)	7
Beam sides walls and columns	1

Stripping of formwork within the time limits listed above does not relieve the Contractor from his responsibility for any damage arising from removal of formwork before the structure is capable of carrying its own weight and any incidental loading.

9.1.2.1.18 Failure to Meet Requirements

Should the strengths shown by the test specimens made and tested in accordance with the above provisions fall below the values given in Table 9.1.2.3, the Engineer shall have the right to request necessary changes in proportions to apply to the remainder of the work. As evidenced by core and/or load tests, the Engineer shall have the right to request strengthening or replacement of those positions or portions of the structure which fail to develop the required strength. The cost of all such core borings and strengthening or concrete replacement required because strengths of test specimens are below those specified, shall be entirely at the expense of the Contractor.

When the tests on control specimens of concrete fall below the required strength, the Engineer will permit check tests for strengths to be made by means of typical cores drilled from the structure in accordance with ASTM Methods C42, "Obtaining and Testing Dried Cores and Sawed Beams of Concrete", and C39 "Compression Strength of Moulded Concrete Cylinders". In case of failure of the latter, the Engineer, in addition to other recourses, may require at the Contractor's expense, load tests on any slabs, beams, piles, pile caps, and columns in which such concrete was used. Load tests need not be made until the concrete has aged 60 days.

Slabs or beams, under load test, shall be loaded with their own weights plus a superimposed load of 0.4 times design dead load plus 6.6 times design live load. The load shall be applied uniformly over the portion being tested in an approved manner and left in position for a 24 hour period and the deflection must not exceed the value:

$$D = \frac{L^2}{2000*h}$$

Where "L" = a span in cm
"h" = a depth of slab or beam in cm
"D" = a deflection in cm

If the deflection exceeds "D" in the above formula, the concrete shall be considered faulty unless within 24 hours after removal of the load, the slab or beam under test recovers at least 75 percent of observed deflection.

9.1.2.1.19 Patching and Repairs

It is the intent to require forms, mixes of concrete and workmanship so that concrete surfaces, when exposed will require no patching.

As soon as the forms have been stripped and the concrete surfaces exposed, fins and other projections shall be removed; recesses left by the removal of form ties shall be filled; and surface defects, which do not impair structural strength, shall be repaired. Clean all exposed concrete surfaces and adjoining work stained by leakage of concrete, to the approval of the Engineer.

Immediately after removal of forms, the Contractor shall remove plugs and break off metal ties as required herein. Holes shall be promptly filled by : moistening the hole with water, followed with a 0.15 cm brush coat of neat cement slurry mixed to the consistency of a heavy paste. The hole shall immediately be plugged with a 1:1.5 mixture of cement and fine aggregate slightly damp to the touch (just short of "balling"). The grout shall be hammered into the hole until dense, and until an excess of paste appears on the surface in the form of a spider web. The surface shall be trawled smooth with heavy pressure.

Form tie holes in the exposed exterior walls and interior walls shall likewise be immediately filled. Extreme care shall be taken to ensure that the colour of the grout used to fill these holes is the same as that of the parent concrete using, if necessary, a mixture of white and grey cement in order to do so.

When patching or repairing exposed surfaces the same sources of cement and sand as used in the parent concrete shall be employed. The colour shall be adjusted if necessary, with the addition of proper amounts of white cement. The surface shall be rubbed lightly with a fine carborundum stone at an age of 1 to 5 days, if necessary, to bring it even with the parent concrete. Care shall be exercised to avoid damaging or staining the virgin skin of the surrounding parent concrete. The surface shall be washed thoroughly to remove all rubbed matter.

Defective concrete and honeycombed areas, as determined by the Engineer, shall be chipped down reasonably square and at least 2.5 cm deep to sound concrete by means of hand chisels or pneumatic chipping hammers. Irregular voids or surface stones need not be removed if they are sound, free of laitence, and firmly embedded in the parent concrete, subject to Engineer's final inspection. If honeycomb exists around reinforcement, the concrete shall be chipped to provide a clear space at least 1 cm wide all around the steel. For areas less than 3.8 cm deep, the patch may be made in the same manner as described above for filling form tie holes, care being exercised to use adequately dry (non-trowelable) mixtures and to avoid sagging. Thicker repairs will require build-up in successive 3.8 cm layers on successive days, each layer being applied as described above. Such repair shall be carried out with the prior approval of the Engineer who will determine whether the defective area is repairable or whether it shall be rejected.

9.1.2.1.20 Construction and Expansion Joints

(1) Construction Joints

A construction joint is defined as a joint in the concrete introduced for convenience in construction at which special measures are taken to achieve subsequent continuity without provision for any relative movement.

The contractor is advised that water stops are not considered necessary in a properly formed construction joint. However, if the Contractor wishes to install water stops in construction joints to

satisfy the requirements of these Specifications then the water stops shall comply with these Specifications and all costs shall be borne by the Contractor.

The Contractor shall submit to the Engineer for his approval, as soon as practicable after the commencement of the Work and not less than one week before the commencement of concreting, shop drawings showing his proposals for placing concrete on which the position and form of all construction joints and lifts shall be shown. No concreting shall be started until the Engineer has approved the method of placing, the positions and form of the construction joints and the lifts.

The construction joints shall be so located as not to impair the structural strength of the completed structure. The position of construction joints and size of formwork panels shall be so co-ordinated that where possible the line of any construction joint coincides with the line of a formwork joint and that in any case all construction joint lines and formwork joint lines appear as a regular and uniform series. For all exposed horizontal joints and purposely inclined joints, a uniform joint shall be formed with a batten of approved dimensions to give a straight and neat joint line. Rebates, keys or notches shall be formed, and water stops inserts as required.

Concrete placed to form the face of a construction joint shall have all laitence removed and the coarse aggregate exposed prior to the placing of fresh concrete. Form retarder may be used to achieve easy removal of the surface concrete with the prior approval of the Engineer. The laitence shall be removed and the coarse aggregate is exposed by "green cutting" -spraying the concrete surface with water under pressure and brushing while it is still green. With the Engineer's prior approval in writing while the concrete is still green the whole of the concrete surface forming part of the joint shall be hacked to expose the coarse aggregate. Where aggregate is damaged during hacking it shall be removed from the concrete face by further hacking. All loose matter shall be removed and the exposed surface thoroughly cleaned by the brushing, air blasting or washing, and the surface to which the fresh concrete is applied shall be clean and damp. Thereafter, fresh concrete may be placed as described in sub-section 9.1.2.1.14.

Construction joints shall generally be located as follows:

Columns: Joints in columns shall be made at the underside of floor members and at floor levels. Haunches and column capitals shall be considered as part of and continuous with the floor or roof.

Suspended floors & roofs Joints in the system shall be located at or near the middle of the spans in slabs, beams or girders, unless otherwise instructed.

Walls: Vertical joints shall be away from corners. Horizontal joints shall be above splays or openings. Construction joints shall be placed at intervals not exceeding 5.0 metres.

Ground slabs. Construction joints shall be placed at intervals not exceeding 5.0 metres.

An order of casting slabs and walls that gives free edges in two direction as right angles shall be followed as far as possible to reduce restraint to free contraction of the immature concrete. The proposed sequence of casting shall be submitted for Engineer's approval before commencement of concreting.

(2) Expansion Joints

Expansion joints are defined as all joints intended to accommodate movement between adjoining parts of a structure, special provision being made where necessary for maintaining the water

tightness of the joint. Expansion joints shall be formed in the locations and to the detailed dimensions indicated on the drawings. Joints where noted on the drawings shall be provided with PVC water stops, joint filler and joint sealer as specified in the drawings or in another section of this specification.

The Contractor shall submit to the Engineer for his approval, as soon as practicable after the commencement of the Work and not less than three weeks before the commencement of concreting, details of his proposals for the installation of water stops. These shall show where joints are to be located and details of the intersections and changes of direction to a scale that shows the position of any joint, or shape of any moulded section.

As far as possible jointing on Site shall be confined to the making of butt joints in straight runs of water-stops. Where it is agreed with the Engineer that it is necessary to make, on site, an intersection, change of direction or any joint other than a butt joint in a straight run, a preliminary joint, intersection or change of direction piece shall be made and subjected to such tests as the Engineer may require.

Flexible water-stops shall be fully supported in the form work, free of nails and clear of reinforcement and other fixtures. Damaged water-stops shall be replaced and during concreting care shall be taken to place the concrete so that water-stops do not bend or distort.

9.1.2.1.21 Field Control

The Contractor shall advise the Engineer of his readiness to proceed, at least 24 hours prior to each concrete placement. The Engineer will inspect the preparations for concreting including the preparation of previously placed concrete, the reinforcing and the alignment and tightness of the form work. No placement shall be made without the prior approval of the Engineer.

The Engineer may have cores taken from any questionable areas in the concrete work such as construction joints and other locations as required for the determination of concrete quality. The results of tests on such cores shall be the basis for acceptance, rejection or determining the continuation of the concrete work.

The Contractor shall co-operate in the obtaining of cores by allowing free access to the work and permitting the use of any ladders, scaffolding and such incidental equipment as may be required. The Contractor at his cost shall repair all core holes to the satisfaction of the Engineer.

9.1.2.1.22 Sleeves, Pipes, and Other Items

The Contractor shall place no concrete until reinforcing steel, pipes, conduits, sleeves, hangers, anchors, and other work required to be built into the concrete have been inspected and approved. All water and foreign matter shall be removed from the forms and excavation. All subgrade below slabs and footings shall be approved by the Engineer before placing concrete.

9.1.2.1.23 Equipment Bases

All steel levelling and bearing plates, machinery and other equipment, bearing on concrete surfaces, shall be bedded on non-shrink grout and where necessary, core holes for anchor bolts shall be fully grouted with non-shrink grout. The grout bed shall not be placed until the member has been aligned, levelled, plumbed and finally secured in position.

The exact dimensions for all equipment bases will depend on the dimensions of the actual equipment furnished. No payment change will be allowed if the dimensions are different from those shown on the drawings.

9.1.2.1.24 Non-Shrink Grout

To aid strength and bonding of multiple layer application of grout the Engineer may order the use of non-shrink additive as follows:

	Proportions	
Material	Volume	Weight
Cement 1.0	1.0	
Coarse Aggregate	0.15	0.25
Fine Aggregate	1.5	1.5
Additives	As recommended by the manufacturer	

Non-shrink grout shall comprise of prepared, size graded aggregate combined with a catalysing agent and water reducing agent. When used in the proportioning of grout, mortar and concrete mixes, shrinkage shall be counter-acted and basic qualities improved. The Contractor shall demonstrate to the Engineer that the product has successfully been utilised on similar projects for a minimum of five (5) years. Preparation of surfaces, mix proportions, application procedures, and precautions shall be followed in strict compliance with the manufacturer's directions.

For very heavy (generally formed) applications, the Engineer may order the addition of pea gravel, passing a 3/8" screen but retained on a 1/4" screen, to the mixture with the proportions modified as follows:

	Proportions	
Material	Volume	Weight
Cement	1.0	1.0
Coarse Aggregate	0.2	0.33
Fine Aggregate	1.0	1.0
Pea Gravel	1.5	1.5
Additives	As recommended by the manufacturer	

In case where coarse aggregate is employed in multiple layers on exposed faces, the final 1.2 cm shall be composed of the 1:1.5 grout without coarse aggregate.

9.1. 2.2 CONCRETE REINFORCEMENT

9.1.2.2.1 Scope of Work

The Contractor shall provide all labour, materials, equipment and incidentals required to furnish and install all steel bars, steel wire, and steel supports required for the reinforcement of concrete as shown on the drawings and specified herein.

9.1.2.2.2 Shop Drawings

The Contractor shall submit bar bending schedules for reinforcing steel prepared in accordance with BS 4466. Engineer's review and approval of shop drawings will apply to the sizes, locations, types of bars and dimensions of bar lap splices only. Dimensions shown on the shop drawings are the responsibility of the Contractor and Engineer's approval of shop drawings shall not constitute approval of dimensions there in.

9.1.2.2.3 Materials

Unless otherwise specified or required, the design, materials, workmanship and erection shall conform to the requirements of BS 8110 and BS 8007.

Reinforcing steel shall conform to BS4449

- Hot rolled mild steel 250 N/mm^2 denoted as "R"
- High yield steel (hot rolled or cold worked) 460 N/mm^2 denoted as "Y"

The high yield steel shall be deformed bar type 2.

Welded Steel Wire Fabric shall conform to BS 4483.
The Tie Wire shall conform to BS 4482 – 1.6 mm black annealed mild steel

Representative samples of all reinforcing steel that the contractor proposes to use in the Works must be submitted, before the work commenced, to the Engineer for his written approval. Manufacturer's certificates which shall be submitted shall clearly state Place of manufacture, All relevant details of composition, manufacture, strength and other qualities of steel.

Frequency of sampling and method of quality control shall be in accordance with Appendix C of BS 4449.

Welding if approved by the Engineer in writing shall conform to AWS D 1.4 or BS 5135.

Bar Size Table

Nominal Diameter(mm)	Weight (kg/m)
6	0.222 Round (Plain)
8	0.395 Round (Plain)
10	0.617 Deformed
12	0.888 Deformed
16	1.579 Deformed
20	2.466 Deformed
25	3.854 Deformed
32	6.313 Deformed

Reinforcing bars will be rejected if the weight of a bundle of one size of bars as delivered is underweight by 3.5 percent or more. An individual bar will be rejected if it is underweight by 6.0 percent or more.

9.1.2.2.4 Fabrication

Reinforcement shall be accurately fabricated to the dimensions indicated on the drawings. Particular care shall be exercised not to have stirrups oversized in order to maintain proper coverage of concrete. Stirrups and tie bars shall be bent around a revolving collar having a diameter not less than two and one-half times the minimum diameter of the bar. Bends for other bars shall be made around a pin having a diameter not less than 6 times the minimum diameter except for bars larger than 25 mm diameter, in which case the bends shall be made around a pin of 8-bar diameter. All bars shall be bent cold. Bars reduced in section or with kinks or bends not shown on the drawings will not be accepted.

9.1.2.2.5 Handling Materials

Reinforcement shall be stockpiled at the site of the work with bars of the same size and shape fastened in bundles with metal identification tags, giving size and mark, securely wired on. The identification tags shall be labelled with the same designations as shown on submitted bar schedules and shop drawings. The Contractor shall submit the mill certified report of test for each shipment of reinforcing steel to the construction site. The certification shall contain the results of chemical and mechanical tests required by the Specification.

All bars shall be stored off the ground and shall be protected from moisture and be kept free from dirt, oil, or injurious contaminants.

9.1.2.2.6 Installation

No reinforcing bars shall be welded either during fabrication or erection without prior written approval from the Engineer. If the Engineer approves the welding of reinforcing bars, the Contractor shall submit a sample of a welded piece together with test results of its strength which shall be not less than such reinforcing bar. Any bars that have been welded, including tack welds, without such approval shall be immediately removed from the work when instructed by the Engineer.

Before being placed in position, reinforcement shall be thoroughly cleaned of loose mill scale, dirt, and other coatings that reduce or destroy bond using sand blasting. Where there is delay in depositing concrete after reinforcement is in place, bars shall be re-inspected and cleaned where necessary.

Reinforcement shall be accurately positioned as indicated on the drawings, and secured against displacement by using iron wire ties of not less than No.18 gauge, or suitable clips at intersections.

All accessories such as chairs and chair-bars are an integral part of the reinforcement and shall be furnished and installed in sufficient quantity to satisfactorily position all steel in accordance with BS 8110 "Code of Practice for Designs of Reinforced Concrete Structures" or ACI 315, "Manual of Standard Practice for Detailing Reinforced Concrete Structures."

Except as otherwise indicated on the drawings, bars in slabs, beams and girders shall be spliced in accordance with the table titled "Minimum Lap Splice Lengths" in BS 8110. Splices and laps in columns, piers and struts shall be sufficient to transfer full stress by bond. Splices in adjacent bars shall be staggered if required.

Except as otherwise indicated on the drawings, reinforcement shall be installed with clearance for concrete coverage in millimetres as follows:

Footing bottoms	75 mm
Formed surfaces in contact with soil or exposed to the weather or water	50 mm
Columns, beams and walls	40 mm
Top and Bottom steel of interior slabs	25 mm
Top and Bottom steel of internal Stairs	25 mm
Top steel in reservoir slabs	50 mm
Bottom steel in reservoir slabs	50 mm
Interior face of walls	40 mm

All slab reinforcing shall be supported on concrete cubes or wafers of the correct height. Wafers shall contain soft steel wires embedded therein for fastening to reinforcing. Wafers shall have a minimum compressive strength equal to that of the concrete in which they are to be placed, and shall have been cured as specified for concrete. Masonry units will not be permitted for supporting steel in bottom mats or elsewhere. For supporting the top steel in slabs, the Contractor shall furnish extra steel supports such as channels if required and shall construct blocks of concrete having the same quality as specified for the structure for use in supporting both top and bottom mat steel. Wood blocks, stones, brick ships, cinder blocks, or concrete building blocks will not be allowed. Alternate methods for supporting top steel in slabs, such as vertical reinforcing fastened to bottom and top mats, may be used if approved.

Alternate methods of supporting bottom reinforcement for slabs and beams not exposed to the weather (such as plastic chairs, but not plastic tipped wire) may be used only if specifically approved by the Engineer.

Reinforcement for vertical surfaces (beams, columns, walls) shall be properly and firmly positioned away from the forms at all points by approved means.

Reinforcement which is to be exposed for a considerable length of time after being placed shall be painted with a heavy coat of neat cement slurry.

In no case shall any reinforcing steel be covered with concrete until the amount and the position of the reinforcement have been checked by the Engineer and his permission given to proceed with the concreting. The Engineer shall be given at least three days notice of the availability of the set reinforcement for checking.

9.1.2.2.7 Straightening Steel

Reinforcing steel shall not be bent or straightened in a manner that will injure the material. Any use of such injured reinforcing steel will not be permitted.

9.1. 2.3 CONCRETE FINISHES

9.1.2.3.1 Scope of Work

The contractor shall furnish all labour, equipment and incidentals necessary to finish cast-in-place concrete surfaces as indicated on the drawings and/or specified herein. The finishes herein specified apply to the surface finish of cast-in-place concrete as it is to be in the finished work, and as it is to be finished to receive additional covering such as plastering.

9.1.2.3.2 Work Specified Elsewhere

Concrete finish for pre-cast concrete elements is specified in Section 9.1.2.5 "Pre-cast Concrete". Painting of concrete, architectural finish coverings, roofing, damp proofing and water proofing are specified elsewhere. Repairs to existing concrete as required to make it suitable for bonding to new concrete or if it is to remain exposed are specified herein.

9.1.2.3.3 General

All concrete surfaces including those not exposed in the finished work such as those that are buried or covered by other material interior of pipeline structures (i.e. man-holes) in accessible

locations shall have all fins burrs and projections removed. The holes and honeycomb areas shall be filled and patched.

Care shall be exercised to prevent rounding chamfered edges or obliterating the bevel line when removing the forms or doing any other work adjacent thereto.

Dusting of surfaces with dry materials to absorb moisture or to stiffen the mix will not be permitted. Sprinkling as an aid to troweling will not be permitted.

The top surfaces of all concrete including separate concrete toppings and walls shall be screeded compacted and floated.

The Contractor shall protect the floors from damage after they have been finished by laying protective timbers and minimising traffic over the areas.

9.1.2.3.4 Types of Finishes for Cast-In-Place Concrete

(1) Cleaned and Patched

All concrete surfaces regardless as to whether they are exposed or not in the finished work shall be cleaned and patched as specified in sub-section 9.1.2.1.19 "Patching and Repairs".

(2) Vertical Surfaces

Vertical surfaces and the undersides of all slabs and beams shall be finished in accordance with the following schedule unless otherwise indicated on the drawings.

Surface Identification	Type of Finish
Exterior surfaces	
Buried	Formed
Exposed	Carborundum
Painted	Rubbed
Tile, etc.	Rough
Interior Surfaces	
Submerged	Carborundum
Exposed	Rubbed
Tile, etc.	Rough
Painted	Rubbed
Miscellaneous	
Stairs except treads	Carborundum
Equipment pads	Carborundum
Surfaces not readily seen	Formed
Plastered	Rough

(3) Types of Finishes

The following describes the types of vertical finishes:

(i) Carborundum Finish

Surfaces shall be rubbed with cement or carborundum bricks and water to remove form marks, and similar blemishes leaving the surface finish uniformly smooth and washed clean.

(ii) Rough Finish

Concrete surface shall be roughened by means of green cutting, hammering or other means to provide a surface texture that will develop a good mechanical bond. The concrete shall be free from paint, oil, dust or any material that might prevent satisfactory bond. Air and water should be used to remove loose material. Hammering shall be done by hand or power tools to expose clean virgin concrete (mortar or aggregate) over the entire surface. Not more than 10 percent of the surface (in any unit of area) shall remain un-chipped.

(iii) Rubbed Finish

Immediately upon stripping forms and before concrete has changed in colour, any fins shall be carefully removed with a hammer. While wall is still damp apply a thin coat of medium consistency neat cement slurry by means of bristle brushes to provide a bonding coat within any pits or blemishes in the parent concrete; avoid coating large areas of the finished surface with this slurry.

Before the slurry has dried or changed colour, apply a dry (almost crumbly) grout comprising one volume cement to 1-1/2 volume of clean masonry sand having a fineness modulus of approximately 2.25. Grout shall be uniformly applied by means of damp (neither dripping wet nor dry) pads of coarse burlap approximately 15 cm. square used as a float. Grout shall be well scrubbed into the pits to provide a dense mortar in the imperfection to be patched. Allow the mortar to partially harden from one to two hours depending upon the weather. Avoid direct hot sunlight. If the air is hot and dry keep the wall damp during this period using a fine, fog spray. When the grout has hardened sufficiently so it can be scraped from the surface with the perpendicular edge of a steel trowel without damaging the grout in the small pits or holes, cut off all that can be removed with the trowel. Grout allowed to remain on the wall too long will get too hard and will be difficult to remove.

Next allow the surface to dry thoroughly and rub it vigorously with clean dry burlap to completely remove any dried grout. No visible film of grout should remain after this rubbing. The entire cleaning operation for any area must be completed the day it is started. Never leave any grout on the wall overnight. Allow sufficient time for grout to dry after it has been cut with the trowel so it can be wiped off clean with the burlap. This process removes slight discoloration and stains and gives a uniformly good appearance without effect on a paint coating.

On the day following the repair of pits and blemishes, the walls again should be wiped off clean with dry used pieces of burlap containing old hardened mortar which will act as a mild abrasive. After this treatment there should be no built-up film remaining on the parent surface. If, however, such is present, a fine abrasive stone must be used to remove all such material without breaking through the surface film of the original concrete. Such scrubbing should be light and sufficient only to remove excess material without working up a lather of mortar or changing the texture of the concrete.

A thorough wash-down with stiff bristle brushes should follow the final scrubbing operation in order that no extraneous materials remain on the surface of the wall. The wall should be sprayed with a fine fog spray periodically to maintain a continually damp condition for at least 3 days after the application of the pit repair grout.

Areas larger than 2.5 cm diameter or 1.25 cm deep should be "day-tamp filled" as for form tie holes. Moisten the hole with water, followed by a 1.6 mm brush coat of neat cement slurry mixed to the consistency of a heavy paste. Immediately plug the hole with a 1:1.5 mixture of cement and sand mixed slightly damp to the touch (just short of balling). Hammer the grout into the hole until dense, and an excess of paste appears on the surface in the form of a spider web. Trowel smooth with heavy pressure. Employ same source of cement and sand as used in the parent concrete. Adjust colour if necessary by addition of proper amounts of white cement and/or limestone screenings. Rub lightly with a fine carborundum stone at an age of 1 to 5 days if necessary to bring the surface plane with the parent concrete. Exercise care to avoid damaging the virgin skin of the surrounding parent concrete.

Wash thoroughly to remove all rubbed matter. If surface ultimately is to be painted, the colour matching may be omitted.

No accelerating admixtures should be employed in surface treatment. An approved admixture may be utilised (in accordance with the manufacturer's directions) to reduce shrinkage and improve durability of the 1:1.5 mixture.

(iv) Formed Finish

All fins and other projections shall be carefully removed, honey-combing repaired form ties cut out and holes patched all as specified under sub-section 9.1.2.1.20 "Patching and Repairs".

(4) Horizontal Surfaces

The top or final surface of all concrete shall be finished in accordance with the following schedule unless otherwise indicated on the drawings.

Surface Identification	Type of Finish
Floors scheduled to be concrete floor	Wood float
Reservoirs and tanks interiors	Light steel trowel
Exposed roof slabs without built-up roofing	Wood float
Exposed roof slabs with built-up roofing	Steel trowel
Equipment pads	Steel trowel
Tile	Light steel trowel
Vinyl asbestos tile	Steel trowel
Pavements, walks and ramps	Broomed
Buried roof slabs	Screeded
Stair treads, interior	Broomed
Platforms	Broomed
Plastering	Broomed

(5) Methods of Finishing

The finishing of concrete surfaces shall not be started until some stiffening of the concrete has taken place. The following describes the types of horizontal finishes.

(i) Screeds

Screeds shall be set as guides so that slabs can be struck true to the required level or slopes shown. Particular care shall be exercised to prevent forming low or depressed areas that do not drain and result in ponding. Screeds shall be sufficiently rigid to resist distortion during the placing and levelling of the slab and shall be accurately set and protected until they are removed. Screeds and their supports shall be completely removed and their recesses filled.

(ii) Wood Float

Following the screeding of the surface to its required level a wood float straight edge shall be worked across the surface to make sure high spots and depressions are eliminated. Floating shall be continued just long enough to produce a true and smooth surface and if a steel trowel finish is required, to bring a small amount of mortar to the surface.

(iii) Broomed

Concrete floors and slabs such as bridge decks and pavements where a non-slippery surface is required shall receive, following screeding, a broomed surface. As soon as the condition of the concrete permits, before it has hardened appreciably (and normally within 4 hours after depositing), all water, inadvertent film, crude laitence, and loose aggregate shall be removed from the surface by means of wire or bristle brooms in such a manner as to leave the coarse aggregate slightly exposed and the surface clean and generally in condition to provide a non-slippery surface. The brooms shall "roll" the film and laitence (if any) from the slab and leave it clean. Avoid "muddying" the surface by brooming too soon. Raking shall not be employed, and large depressions and general unevenness shall not be allowed.

If, in the opinion of the Engineer, the surface finish is not properly done and the resulting surfaces are unsatisfactory, the Contractor shall chip the surface to the satisfaction of the Engineer.

(iv) Steel Trowel

Steel troweling may be commenced as soon as the wood floated surface has hardened enough to prevent an excess of fines from working to the surface. This operation is to be performed by power driven troweling machines as approved by the Engineer to produce a dense smooth surface free from blemishes. Troweling too soon or excessive troweling in one operation produce an unsound finish. Where a light steel trowel finish is specified light hand troweling shall be used.

9.1.2.3.5 Cement Plastering

(1) General

Plastering shall consist of Portland cement plaster applied to the limits and lines indicated on the drawings. The thickness indicated on the drawings are the minimum thickness required and additional thickness will be required to provide for any unevenness in the masonry surface. In the event the average complete plaster thickness over an area in excess of 5 square meters will exceed 5 cm, a galvanised wire reinforcing square mesh of weight not less than 1.4 kg/sq. m shall be attached to the masonry and plastered into base coat. Before plastering all grounds and corner bends shall be firmly secured in place. Concrete masonry and brick surfaces shall have sufficient roughness to provide proper bond and shall be dampened by brushing or spraying with clean water followed by a primary coat of Portland cement. Where the finished plastering is to be greater than 2 cm thick it shall be applied in two coats, a base course not less than 1.5 cm thick and a finish coat not to exceed 1.5 cm thick.

The base coat of plastering shall be of a mix proportion of 350 kg of cement, and one (1) cubic meter of medium sand. The finish coat shall be in the proportion of 280 kg of cement and one (1) cubic meter of medium sand. Leaner mixes shall only be allowed with the permission of the Engineer. The sand shall be clean, durable particles, free from injurious amounts of organic matter and shall conform to the limits of ASTM C144, "Aggregate for Masonry Mortar."

Before the base coat has hardened it shall be evenly scored to assist in bonding the finish coat. When the base coat has hardened enough to receive the finish it shall be dampened and the finish coat applied. The finish coat shall give the appearance of a rubbed finish herein before specified or as otherwise required to match surrounding surfaces.

Plastered surfaces shall be shielded from the direct rays of the sun for two days and shall be kept moist but care shall be taken not to wash out cement.

(2) Repair of Damaged Concrete

Where concrete is cut and removed to provide for new work, concrete surfaces will be formed which will require finishing. The two surface conditions considered herein are namely, damaged surface which are to be cleaned and plastered, and exposed in the finished work; and the surface to be incorporated in the new work. The only requirement for damaged concrete surface not to be exposed is that reinforcing steel be cut off flush with the concrete surfaces.

Bonding existing concrete to new structural concrete and damaged concrete against which new concrete is to be placed shall be thoroughly cleaned to remove any loose concrete. Reinforcing steel shall be straightened and incorporated in the new work as required. A neat cement slurry shall be applied to the existing surface just prior to placing new concrete.

Plastering of existing concrete damaged in connection with the new work and exposed to view shall be in conformance with the above specification with the added requirement that a bonding admixture be incorporated into the plastering cement. The bonding admixture shall be an additive to the concrete mix made from natural or synthetic rubber or an organic polymer or copolymers and applied in accordance with the manufacturer's instructions.

9.1.2.3.6 Other Surfaces

All exposed edges shall be chamfered as specified on each side unless otherwise noted on the drawings. Care shall be exercised to prevent rounding these edges or obliterating the bevel line when removing the forms or doing any other work adjacent thereto.

9.1.2.3.7 Cleaning

All exposed concrete surfaces and adjoining work stained by leakage of concrete shall be cleaned.

9.1. 2.4 CONCRETE JOINTS

9.1.2.4.1 Scope of Work

The Contractor shall provide all labour, material, equipment and incidentals required to furnish and install all joints in structural concrete as detailed on the drawings and specified herein. Included are the materials required to complete expansion, contraction and construction joints including water-stops, fillers and sealant.

9.1.2.4.2 General Requirements

(1) Water Stops

All vertical and horizontal expansion joints in concrete slabs and peripheral walls of structures and conduits conveying or containing liquid shall have water-stops, unless specifically noted otherwise on the drawings. This requirement does not apply to construction joints.

(2) Suppliers

All concrete jointing elements herein specified shall be furnished by a supplier that can give satisfactory evidence to the Engineer that they are capable of supplying the quantities for the schedule required and has an organisation that is knowledgeable in the installation of these systems. A competent representative of the supplier shall instruct in the installation of these systems.

9.1.2.4.3 Materials

(1) Water-stops

Samples of all materials to be furnished under this Section shall be submitted to the Engineer for approval.

1) Materials shall be sourced and supplied by a single manufacturer with a minimum of ten years experience.

2) Manufacturer shall operate a quality system which is registered to ISO 9001 or approved equal.

3) Technical back-up service during installation shall be provided by the manufacturer at no additional cost to the Employer.

4) Material

   a) Unless otherwise specified all water-stops shall be extruded from a high grade elastromeric polyvinyl chloride compound as basic resin and manufactured from virgin materials necessary to meet the performance requirements of this specification.
   b) Comply with the requirements of BS 2782 or US Corps of Engineers specification CRD C572-74.
   c) Suitable for storage, handling, installation and service within a range of 15° C to 50° C.
   d) Shall be dumbbells type both for internal and external rear guard as specified in the drawings. The water-stops shall have dumb bells 250 mm width with a centre bulb, minimum web thickness of 9.5 mm. The centre bulb shall have a minimum inside diameter of 20 mm & minimum outside diameter of 40 mm. The edge rib shall have a dumb bell of minimum of 25 mm diameter. The external or rear guard water stop shall be 250 mm wide with three bulbs. The centre bulb shall be a box section 25 mm wide which is flat to accept a filler board. To prevent the water-stops folding during concreting & assist in keeping firmly in position all water stops shall be provided with steel chips along both edge ribs at spacing not more than 500 mm. The water stop shall be held firmly to the reinforcement steel to the satisfaction of the Engineer with wire of No.12 gauge.

   e) Intersection & Transition pieces shall be performed factory moulded type and or factory prefabricated type.

      - Site jointing shall be limited to butt joints and shall be strictly in accordance with the manufacturer's instructions.
      - Joints shall be heat sealed.

f) Physical Properties:

Property	Test Method	Minimum Requirements
Tensile Strength	ASTM D 638	14.5 N/mm^2
Ultimate Elongation	ASTM D 638	370%
Tear Resistance	ASTM D 624	50 kN/m
Stiffness in Flexure	ASTM D 747	4.14 N/mm^2
Hardness, shore A/15	ASTM D 2240	70 to 80
Water Absorption	ASTM D 570	max 0.3%
Tensile Strength after accelerated extraction	CRD – C 572	13.5 N/mm^2
Elongation after accelerated extraction	CRD – C 572	300%
Specific Gravity	ASTM D 792	max 1.4
Low Temperature Brittleness	ASTM D 746	No failure at - 37°C
Volatile Loss	ASTM D 1203	Max 0.5%
Effect on Alkali after 7 days: Weight Charge	CRD – C 572	Max + 0.25% - 0.10%
Hardness Change		Max ± 5%

Testing shall be carried out in accordance with BS 2782 or US Corps Engineers specification CRD C572-74.

(2) Joint Filler Board

1) Non-absorbent, semi rigid, cross linked closed cell, heat laminated polyethylene filler board.
2) Non-tainting and rot proof in accordance with BS 6920
3) Fully compatible with the surface sealant and if elastometric sealant are used the joint filler shall act as a bond breaker.
4) Sheet form in one layer to the thickness as detailed on the Drawings.
5) Performance Properties:

a. Recovery : greater than 98% after 50% compression
b. Water Absorption : < 0.05% by volume
c. Compressive Strength : min 0.15 N/mm^2
d. Density : 100kg/m ± $5kg/m^3$
e. Extrusion : Nil (three edges restrained & sample compressed by 50%)

(3) Joint Sealant

1) Two part polysulphide complying with BS 4254 or FS TT-S-00227E,Type II,Class A.
   a) Must in all cases be carefully selected as appropriate for their climatic and environmental exposure.

2) Hardness Shore A : min 25
3) Movement Accommodation Factor : min 25%
4) polymer Content : min 25% (for normal grade)
5) Resistance to weathering, ozone, ultra-violet light, chemicals and biodegradation
6) Ability to withstand repeated cycles of compression and expansion over a wide temperature range

(4) Bond Breaker

Forced, non-absorbent polyethylene backing strip or equals as recommended by sealant manufacturer to prevent adherence of sealant to backup material

(5) Slip Membrane

- Pre-formed low friction bearing strip to form a thin sliding joint minimum bearing capacity of 0.7 N/mm^2
- Extruded from specially formulated polyethylene to form a durable lamina, resistant to most chemicals, solvents and weathering.
- Applied in two layers with bottom layer bonded to substrate with high quality solvent borne adhesive based on polychloroprene rubber.
- Thickness 1.5 mm
- Coefficient of friction 0.15
- Operating temperature upto 50^0C.

(6) Sealing Strip Membrane

Where indicated on drawings, expansion joints shall be sealed with a sealing strip system. The joints shall be pre-sealed using sealant prior to laying sealing strip membrane. Sealing strip system shall comprise of hypalon high-polymer flexible sheeting bonded to the concrete surfaces on either side of joint using suitable epoxy resin adhesive. The system proposed shall have high performance allow for considerable movement in more than one direction while maintaining a high quality seal. Width of flexible membrane shall be 250 mm. Minimum thickness shall be 3.0 mm. Minimum un-bonded width shall be 50 mm centre on the joint to allow for greater movement potentials. Final sealing strip system shall be able to accommodate movement which results in the de-bonded area being extended up to 100% of the de-bonded width.

Performance properties shall be as follows:

- Density : 1.65 kg/litre (adhesive) 1.50 $kg/^{m2}$ (hypalon Lmm)
- Service Temperature : -30^0C to $+ 70^0C$
- Bond strength to concrete : Dry or Damp = $-4N/mm^2$ (concrete failure)
- Tensile Strength : $-6N/mm^2$
- Peel Strength : $-4.5\ N/mm^2$
- Elongation : > 400%

(7) Waterproof Membrane.

Waterproof membrane shall be self-adhering sheet membrane consisting of rubber modified asphalt compound such as Bituthene 1000 coated to one side of a polyethylene film. The membrane

shall have a minimum overall thickness of 1.5 millimetres and a tensile strength of 140 kN/sq. cm and shall in all respects comply with the requirements of BS 102.

Primer : Special compound provided by the self-adhering manufacturer, formulated for its intended use.

Installation : The reservoir roofs and sump roofs shall be protected with self-adhering water proofing membrane.

Over the cleaned concrete surface the Contractor shall apply primer in manner and using quantities in accordance with the membrane manufacturer's printed instructions. After the primer has dried, the Contractor shall apply the self-adhering membrane to the concrete without stretching, with polyethylene face out. It shall be smoothed down with a small roller.

The contractor shall apply the membrane sheets with 120 mm overlaps at edges and ends, rolled down firmly and completely.

(8) Bearing Strips

The bearing strips shall have bearing core 50 mm or 75 mm made out of Elastomeric neoprine confirming to Standard Specification for Highway Bridges adopted by the American Association of State Highway Transportation Officials or to BS 5400.

Performance properties shall be as follows:

Safe load capacity =100 kN/m length
Overall displacement = 2+ or - 10 mm
(single initial 7 mm followed by working movement of ± 3 mm transverse
± 2.0 mm longitudinal
The bearing area shall be surrounded with expanded polystyrene to facilitate insitu pouring of superstructure concrete. An adhesive shall be used (non solvent type) to fix the bearing pad to the base concrete.

9.1.2.4.4 Installation

Water stops for all joints shall be continuous around all corners and intersections. Splices shall be made in accordance with the manufacturer's recommendations, subject to the approval of the Engineer.

Particular care shall be taken to correctly position the water-stop during installation and prevent it being moved or distorted by the concrete placement. The water-stops shall be thoroughly cleaned immediately prior to placing concrete. Adequate provision shall be made to support the water-stop during the progress of the work and to ensure proper embodiment, symmetrical about the joint. When PVC water stops are to be left for future connections they shall be protected by wood covers.

Joint filler shall be installed at the locations and according to the details shown on the drawings.

Joint sealers shall be placed to the width and depth shown on the drawings. Surfaces in contact with sealers shall be clean, dry and firm with all traces of form oil or other coatings removed. Preparation of surfaces, priming, and the handling and preparation of materials shall be in complete compliance with the manufacturer's instructions.