
L – CONCRETE WORK

1.0 CONCRETE

1.1 *Scope*

This section covers the supply of materials for concrete, design of concrete mixes, quality control of concrete, mixing, transporting, placing and curing of concrete, and testing of concrete.

The standard of materials and workmanship shall not be inferior to the recommendations of the current:

- British Standard 8110 : Structural Use of Concrete
- British Standard Code of Practice BS 8007 1987: Design of Concrete Structures for Retaining Aqueous liquids.
- Appropriate Malaysian Standards approved by the S.O.

Unless otherwise specified, all reinforced concrete for retaining aqueous liquids shall comply with BS 8007 and shall be of Grade C35A designed to resist Class 2 Sulphate Conditions as defined in BS 5238: Part 1 Table 7.

1.2 *Concrete Production at the Site*

At the commencement of the Contract the Contractor shall submit for the approval of the S.O. a method statement detailing with regard to the requirements of this Specification his proposal for the organization of concreting activities at the site.

The method statement shall include the following items :-

- (a) Plant proposed;
- (b) Laying of concrete production facility;
- (c) Proposed method of organisation of the concrete production facility;
- (d) Quality control procedures for concrete and concrete materials;
- (e) Method of transport and placing of concrete;
- (f) Striking times for formwork and procedure for temporary support of beams and slabs.

1.3 *Test Certificates*

Unless otherwise directed by the S.O., manufacturer's test sheets shall be supplied with each consignment of cement and admixture certifying compliance with the relevant standard.

The Contractor shall also submit to the S.O. certificates of calibration for the weighing and dispensing equipment on the concrete batch mixing plant, certified test results for all tests carried out on aggregate, water, fresh concrete and hardened concrete, all as specified.

1.4 Aggregate Samples

Prior to the commencement of the trial mixes of concrete the Contractor shall submit for approval samples 50 kg in weight of each aggregate which he proposes to use.

The source of each aggregate shall be clearly marked on the container of each sample.

Certified test results demonstrating compliance with the relevant quality standard shall be submitted at the same time. Samples approved by the S.O. shall remain preserved at site for reference.

1.5 Records of Concreting

An accurate and up to date record showing dates, times, weather and temperature conditions when various sections of the works are concreted shall be kept by the Contractor and shall be available for inspection by the S.O. The Contractor shall also record the results of all tests of concrete and shall identify these results with the parts of the works of which the samples material is representative.

For each grade of concrete, the Contractor shall submit to the S.O., not later than twenty-four hours after concreting, a daily return of the number of batches mixed, the number of batches and total volume of concrete placed, the number of batches wasted or rejected and the weight of cement used.

The return shall also include specific details of each location in the works where concrete is placed, together with the grade of concrete, total volume of concrete placed and the number of batches used for each location.

1.6 Concrete Mixes

At the commencement of the works the Contractor shall design a mix for each grade of concrete which will be required for use in the works and shall submit full details of the mix designs to the S.O. for his approval. Each mix design shall be according to the requirements of BS 5328.

1.7 Construction Joints and Lifts

The Contractor shall submit to the S.O. for his approval, as soon as is practicable after the acceptance of his tender and not less than three weeks before the commencement of concreting, drawings showing his proposals for placing concrete on which the position of all construction joints and lifts shall be shown. No concreting shall be started until the S.O. has approved the method of placing, the positions and form of the construction joints and the lifts. The construction joints shall be located so as to impair the strength of the structure.

Rebates, keys or notches shall be formed and waterstops inserted as the S.O. may require. The position of construction joints and the size of formwork panels shall be so coordinated 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.

1.8 Cement

The cement used for any particular mix shall comply with whichever of the following standards is relevant :-

Ordinary Portland cement	BS 12
Sulphate-resisting Portland cement	BS 4027
Portland Pulverised-Fuel Ash cement	MS 1227
Portland Blastfurnace Cement	MS 1389

For water retaining structures, the cement used shall be a blended cement comprising ordinary portland cement from an approved source and conforming to BS12 and containing 25%, by mass, of pulverised fly ash (PFA) to the requirement of MS 1227, or containing 50%, by mass, of ground granulated blast furnaced slag (GGBS) to the requirement of MS 1389. The cement used shall be an approved brand of Malaysian manufacture unless otherwise approved.

In addition to the requirements for soundness of cement given in the relevant British Standard for the type of cement being used, the cement shall also be tested for soundness in accordance with ASTM C151-77 'Standard Test Method for Autoclave Expansion of Portland Cement'. The expansion of the cement bar resulting from this test shall not exceed 0.8 percent.

The Contractor shall provide from each consignment of cement delivered to the site such samples as the S.O. may require for testing. Any cement which is, in the opinion of the S.O., lumpy and partially set shall be rejected and the contractor shall promptly remove such cement from the site. Cement which has been stored on the site for more than forth days and cement which in the opinion of the S.O. is of doubtful quality shall not be used in the works unless it is retested and the test results show that it complies in all respects with the relevant standard.

1.9 Storage of Cement

Immediately upon arrival at the site, cement shall be stored in silos designed for the purpose or in dry weather-tight and properly ventilated structures with floors raised 500 mm above ground level with adequate provision to prevent absorption of moisture. All storage facilities shall be subject to approval by the S.O. and shall be such as to permit each access for inspection and identification. Each consignment of

cement shall be kept separately and the Contractor shall use the consignments in the order in which they are received.

Cement of different types and from different sources shall be kept in clearly marked separate storage facilities. Cement delivered to the site in drums or bags provided by the supplier or manufacturer shall be stored in the unopened drums or bags until used in the works.

Any cement in drums or bags which have been opened on the site shall be used immediately or shall be disposed of.

1.10 *Aggregates*

Aggregates for concrete shall be obtained from an approved source and shall conform with the requirements of BS 882.

Sampling and testing of aggregates shall be carried out as required by S.O in accordance with the requirements of the appropriate clauses of BS 812. Water absorption of aggregates when tested in accordance with the standard procedure prescribed in Part 2 of BS 812, shall not exceed 3%.

The aggregates to be supplied shall not give rise to any alkali reaction with the cement, whether silica or carbonate. Potential reactivity or otherwise of aggregates shall be determined in accordance with ASTM C 289.

In addition, the soluble chlorides and sulphates content of the aggregates shall be such that the concrete mix as a whole complies with the specified limits of salt content.

Tests for chlorides and sulphates and for potential alkali reaction shall be carried out when required by the S.O.

Notwithstanding any provisions contained herein, limestone aggregates shall not be used in underground and water retaining structures.

1.11 *Storage of Aggregates*

The Contractor shall provide means of storing the aggregates at each point where concrete is made such that :

- (i) Each nominal size of coarse aggregate and fine aggregate shall be kept separated at all times;
- (ii) Contamination of the aggregates by the ground or other foreign matter shall be effectively prevented at all times;
- (iii) Each heap of aggregate shall be capable of draining freely.

The Contractor shall ensure that graded coarse aggregates are tipped, stored and removed from store in a manner that does not cause segregation.

Wet fine aggregate shall not be used until, in the opinion of the S.O., it has drained to a constant and uniform moisture content of the fine aggregate continuously and adjusts the amounts of fine aggregate and added water in each batch of concrete mixed to allow for the water contained in the fine aggregate. If necessary to meet the requirements of this clause, the Contractor shall protect the heaps of fine aggregate against inclement weather.

1.12 Water

Water for washing aggregates and for mixing concrete and curing shall be clean and free from harmful matter and shall satisfy the recommendations in the Appendix to BS 3148. When required by the S.O. the Contractor shall take samples of the water being used for which it is proposed to use for mixing concrete and test them for quality, including determining the concentration of sulphates and chlorides, which shall be such that the concrete mix as a whole complies with the specified limit for salt content.

1.13 Admixtures

Admixtures shall mean material added to the concrete materials during mixing for the purpose of altering the properties of the concrete mix.

Admixture containing calcium chloride shall not be used.

Admixtures shall not be used unless the S.O. has given his prior approval in writing for each instance. Both the amount added and the method of use shall be to the approval of the S.O. who shall also be provided with the following information :-

- (i) The typical amount added and the detrimental effects if any, due to an increase or decrease in this amount;
- (ii) The chemical name(s) of the main active ingredient(s) in the admixture;
- (iii) Whether or not the admixture leads to the entrainment of air when used at the amount the manufacturer recommends.

Any approved admixture shall conform to whichever of the following standards is appropriate :-

- | | |
|--|----------------|
| - Air entraining admixtures | BS 5075 Part 2 |
| - Water reducing admixtures | BS 5075 Part 1 |
| - Retarding admixtures | BS 5075 Part 1 |
| - Fly ash and raw or calcined natural pozzolans for use as a mineral admixture | ASTM C 618 |

1.14 Test Equipment

The contractor shall furnish all equipment and materials necessary for collecting samples and carrying out field laboratory tests on materials for concrete and on fresh and hardened concrete. Laboratory equipment shall be housed in a suitable laboratory building on the site, which shall also incorporate space for storage of field test equipment, and for curing of concrete test cubes in an orderly manner so that they are readily accessible for testing on the due date. The contractor shall also furnish all weights, containers and other equipment necessary for testing the weight-batching equipment for concrete materials and the dispensers for admixtures.

1.15 Grades of Concrete

Grades of concrete for use in the work shall be as shown in the table below:-

Concrete grade	Maximum aggregate size (mm)	Characteristic strength at 28 days (N/sq.mm)	Minimum cement content (kg/cu.m)	Maximum Cement content (kg/cu.m)	Maximum free water/cement ratio
C40	20	40	325	550	0.55
C35A**	20	35	325	400*	0.55**
C35A**	40	35	300	550	0.60
C30	20	30	275	550	0.65
C25	20	25	250	550	0.70
C20	20	20	225	550	-
C15	20	15	205	550	-

* Maximum cement content 400 kg/m³ where OPC or cement containing GGBS is used. Maximum cement content 450 kg/m³ where cement containing PFA is used.

** Maximum free water cement ratio is 0.55 where OPC or cement containing GGBS is used. Maximum free water cement ratio is 0.50 where cement containing PFA is used.

*** Blended cement comprising Portland cement and PFA or PFA as specified

Concrete grade is that number which represents its 28 day characteristic strength expressed in N/sq.mm.

Characteristic strength is that value of cube crushing strength below which none of all test results fail. This condition shall be deemed to be satisfied when test results comply with the specified test requirements.

Maximum free water/cement ratios shall be based on aggregates being in a surface-dry condition.

1.16 Free Water/Cement Ratio

In designing and establishing approved mixes of concrete for any part of the works the contractor shall keep strictly within the limitations on free water/cement ratios which may be shown on the drawings or expressly stated elsewhere as applying to concrete for particular parts of the works.

1.17 Limits of Salt Content

No concrete shall contain more than the following total quantities of substances expressed as percentages by weight of cement :-

- (a) For mixes containing ordinary Portland cement to BS 12 :
Total water soluble chlorides 0.4% (as chloride ions)
- b) For mixes containing cements complying with BS 4027 :
Total chlorides 0.2% (as chloride ions)
- c) For mixes used for pre-stressed concrete (all cement types) :
Total chlorides 0.1% (as chloride ions)
- d) For all mixes :
Total acid soluble sulphates 4.0% (as SO₃ ions)

Tests shall be carried out in accordance with the following standards :-

- Chlorides in aggregates ASTM D 1411
- Sulphates in aggregates BS 1377 Test 9
- Chloride ion in mixing water ASTM D 512
- Sulphates in mixing water ASTM D 516

1.18 Workability

The workability of each grade of concrete shall be such that satisfactory compaction can be obtained when the concrete is placed and vibrated and that there is no tendency to segregate when it is handled, transported and compacted by the methods which the contractor proposes to use in the works.

For reinforced concrete, the compacting factor, determined by the method described in BS 1881, shall not be less than 0.85 nor greater than 0.92. For unreinforced concrete the compacting factor shall be not greater than 0.85. Where

pumping of concrete is permitted, the compacting factor may be increased to 0.95, provided that the conditions are not varied. In any case no pumped concrete shall be used for all water retaining structures.

1.19 ***Design of Concrete Mixes***

Each mix design shall be such that :

- (i) The aggregate shall comprise both fine aggregate and coarse aggregate. The maximum size of coarse aggregate shall be 20 mm or 40 mm as approved by the S.O.
- (ii) The cement content shall not be below the minimum specified for the grade of concrete.
- (iii) The maximum free water/cement ratio shall be the maximum water/cement ratio when the aggregate is saturated but surface dry.
- (iv) The mixes shall be designed to produce a targeted mean concrete cube strength at 28 days after manufacture and shall be greater than the characteristic strength at 28 days by a margin of at least 10 N/sq.mm for Grade 15 and 15 N/sq.mm for Grade 20, 25, 30, 35A and 40.
- (v) Where sufficient data can be produced by the contractor to show that the standard of acceptance for characteristic strength can be maintained using a lower margin, the mix may be redesigned to have such reduced margin. Sufficient data shall consist of cube test results from at least 40 separate batches of concrete produced over a same plant under similar supervision. The reduced margin shall be 1.64 times the standard deviation of the test results considered, but not less than 5 N/sq.mm for Grade 15 and 7.5 M/sq.mm for Grades 20, 25, 30, 35A and 40.

For any concrete containing admixtures, the strengths shall not be less than those specified but the mixes for the grade of concrete shall be separately designed to take account of the effects of the admixtures, and shall have separate trial mixes made and tested.

1.20 ***Trial Mixes***

As soon as the S.O. has approved each of the concrete mix designs, two batches from a trial mix for each grade shall be produced in laboratory using cement and surface dry aggregates known to be typical of the proposed source of supply. The proposed mix proportions of each grade shall be approved only if both batches have the correct cement content and free water cement ratio at or below the maximum value for the proposed degree of workability.

When mix proportions have been approved by the S.O., three further batches of concrete for each grade shall be made at site under full scale production conditions using the same mixing time and handles by means of the same plant which the Contractor proposes to use in the works.

The proportions of cement, aggregates and water, shall be carefully determined by weight in accordance with the contractor's approved mix design, and sieve analyses shall be made, by the method described in BS 812, of fine aggregate and each nominal size of coarse aggregate used.

The compacting factor of each batch of each trial mix shall be determined immediately after mixing by the method described in BS 1881 and shall not be outside the limits specified in clause 2.3.18.

Three 150 mm compression test cubes from each of the three batches shall be made by the Contractor in the presence of the S.O. from each trial mix. The cubes shall be made, cured, stored and tested at 28 days after manufacture in accordance with the method described in BS 1881. If the average value of the compressive strength of the nine cubes taken from any trial mix is less than the target mean strength used in the mix design or if any individual cube test result falls below 85% of the target mean strength, the Contractor shall redesign that mix and make a further trial mix and set of test cubes.

A full scale test of the workability of each trial mix of each grade of concrete shall be made by the contractor in the presence of the S.O. The trial mix of each grade of concrete shall be batched, mixed and then transported a representative distance in the manner that the contractor proposes to batch, mix and transport the concrete to be placed in the works. After discarding the first batch so made, the concrete from later batches shall be placed and compacted in trial moulds both for reinforced and mass concrete with dimensions typical of the works in accordance with the procedures described in later clauses, the sides of the moulds being capable of being stripped without undue disturbance of the concrete placed therein. The sides of the moulds shall be stripped after the concrete has set and the workability judged by the surface appearance and compaction obtained. If the workability test shows that the workability required is not attained for any trial mix for any grade of concrete, the trial mix shall be re-designed by the Contractor and a further full scale workability test undertaken for that trial mix.

The re-design of the concrete mixes and the making and testing of trial mixes of concrete shall be repeated for each grade of concrete until trial mixes of concrete have been established which meet the specified requirements and have the required workability as demonstrated in the full scale workability test described above.

If at any time during the construction of the works the S.O. approves a change in the source of cement or aggregate or if the grading of the aggregate alters to such an extent that the fraction of aggregate retained on any sieve cannot be maintained within two percent of the total quantity of fine and coarse aggregate when adjusted as specified for sampling and testing of aggregates, then further trial mixes of concrete shall be made, tested and approved for use.

1.21 Material Batching

All cement used in the manufacture of concrete shall be measured by weight either with an approved weighing machine or by making the size of each batch of concrete such as to require an integral number of complete bags or drums of cement.

For concrete of Grades 20, 25, 30, 35A and 40, the fine aggregate and the several nominal sizes of coarse aggregates shall be measured singly or cumulatively by weight using weight-batching machines.

For concrete of Grade 15, the fine and coarse aggregate shall be measured separately either by weight using weight-batching machines or by volume in gauge boxes.

Weight-batching machines shall provide facilities for the accurate control and measurement of the aggregates either singly or cumulatively and shall be capable of immediate adjustment by semi-skilled operators in order to permit variations to be made to the mix. All weigh dials shall be easily visible from the place at which filling and emptying of the hoppers is controlled.

Every concrete mixing machine shall be fitted with a device to measure added water by weight and shall be so constructed that the water inlet and outlet valves are interlocked so that either one of them cannot be opened unless the other is fully closed. The weighing device shall be provided with an overflow with a cross-sectional area at least four times that of the inlet pipe and with its discharge point clear of the mixing plant. The entire water system shall be maintained free of leaks at all times and the measuring device shall be fitted with a drain pipe which allows the full quantity of water being measured to be drained off for checking the measurement. The outlet arrangement of the measuring device shall be such that between five and ten percent of the water enters the mixer before the other materials and further five to ten percent of the water enters the mixer after the other materials. The remainder of the water shall be added at a uniform rate with the other materials. The water measuring device shall be readily adjustable so that the quantity of water added to the mixer can, if necessary, be varied for each batch.

Where volume batching is permitted by the Specification, gauge boxes shall be soundly constructed of timber or steel to contain exactly the volume of the various aggregates required for one batch of each mix. They shall have closed bottoms and shall be clearly marked with the mix and aggregate for which they are intended.

When calculating the size of the gauge box for fine aggregate, an allowance shall be made for the bulking of the fine aggregate due to the average amount of moisture contained in the stockpiles on the site. Before the contractor puts any gauge box into use on the site he shall obtain the approval of the S.O. of the size and construction of such gauge box.

Any admixtures which may be used shall be measured separately in calibrated dispensers.

All mixing and batching plants shall be maintained free of set concrete or cement and shall be clean before commencing mixing. The accuracy of calibration of any weighing plant, water measuring plant and admixture dispenser, shall be checked before carrying out trial mixes, before mixing concrete for inclusion in the work, after each service or adjustment to the mixing plant, and in any case at least once per month.

1.22 *Mixing Concrete*

Concrete shall be mixed in batches in plant capable of combining the aggregates, cement and water (including admixtures, if any) into a mixture uniform in colour and consistency, and of discharging the mixture without segregation.

On commencing work with a clean mixer, the first batch shall contain only half the normal quantity of coarse aggregate to compensate for the adhesion of the other materials to the drum.

The moisture contents of the aggregates shall be determined before the commencement of each day's concreting and at such intervals during each day as may be necessary. The Contractor shall make due allowance for the water contained in the aggregates when determining the quantity of water to be added to each mix, and shall adjust the amount of water added to each mix to maintain constant the approved free water/cement ratio of the mixed concrete.

1.23 *Ready-Mixed Concrete*

Ready-mixed concrete shall not be used in any part of the works without the S.O.'s written approval, which may be withdrawn at any time.

The Contractor shall satisfy the S.O. that ready-mixed concrete complies with the Specification in all respects, add that the manufacturing and delivery resources of the proposed supplier are adequate to ensure proper and timely completion of each concreting operation.

The specified requirements as to the sampling, trial-mixing, testing and quality of concrete of various grades shall apply equally to ready-mixed concrete which shall furthermore be made and delivered in accordance with BS 5328 : 1981.

Any additional facility, which the S.O. may require for the supervision and inspection of the batching, mixing and transporting of ready-mixed concrete shall be allowed to be used after 45 minutes of initial mixing.

1.24 *High Alumina Cement*

The composition of high alumina cement shall comply with B.S. 915 Part Two. It shall consist of a minimum of 32% of alumina and the minimum compressive strengths of mortar cubes at one and three days shall be 42 N/sq.mm and 48 N/sq.mm respectively.

High alumina cement shall be refrained from being used in structural concrete including foundations as a substantial reductions in strengths is observed under the vulnerable tropical conditions.

1.25 *Preparing for Concreting*

Before placing concrete the contractor shall remove from the surface of the foundations or previously placed concrete, all oil, loose fragments of rock, earth, mud, timber and other debris, and standing water, to the satisfaction of the S.O.

Where specified and elsewhere as ordered by the S.O., the excavated surfaces shall be prepared as specified under concrete protection.

1.26 *Transporting Concrete*

Concrete shall be conveyed from the mixer to its place in the works as rapidly as possible by methods which will prevent segregation or drying out and ensure that the concrete is of the required workability at the time of placing. If segregation has nevertheless occurred in any instance, the materials shall be remixed or rejected.

1.27 *Placing Concrete*

Concrete shall be placed and compacted before the initial set has occurred and, in any event, not later than 45 minutes from the time of mixing.

When pneumatic placers are used, if the end of the placer pipe is not equipped with an energy absorbing device, it shall be kept as close to the work as practicable. Mortar or water used at the beginning or end of a run shall be discharged outside the formwork..

When pumps are used, the end of the supply pipe shall be kept immersed in the concrete during placing to assist compaction. Mortar and water used at the beginning or end of a run shall be discharged outside the formwork.

1.28 *Concreting in Hot Weather*

In hot weather, the contractor shall take steps to ensure that the temperature of the concrete as placed shall not exceed 32 deg. C and that the maximum internal temperature attained during setting does not exceed 70 deg. C.

To achieve this, the contractor shall provide sun shades over stockpiles of aggregate, cement silos, mixing water tanks and pipelines and in addition shall carry out the first and as necessary other of the following procedures which shall be submitted to the S.O. for approval :

- (i) Cool the mixing water and replace part of the water by chipped ice. The ice shall be completely melted by the time mixing is completed.
- (ii) Spray clean cool water over the aggregate stockpiles. The Contractor shall carry out regular tests on the aggregates to ensure that concentrations of sulphates or chlorides do not rise to unacceptable levels, and to ensure that moisture content determinations allow for such spraying.
- (iii) Shade or wet outside of the formwork.

- (iv) Apply a fine moisture (fog) spray of clean cool water to shaded areas immediately prior to placing concrete.
- (v) Pour concrete at night.

1.29 *Compaction*

All concrete placed in-situ shall be compacted with power driven internal type vibrators supplemented by hand spading and tamping except as otherwise approved by the S.O. The vibrators shall at all times be adequate in number, amplitude and power to compact the concrete properly and quickly throughout the whole of the volume being compacted. Spare vibrators shall be readily on hand in case of breakdown.

Vibrators shall be inserted into the uncompacted concrete vertically and at regular intervals. Where the uncompacted concrete is in a layer above freshly compacted concrete the vibrator shall be allowed to penetrate vertically for about 100 mm into the previous layer. In no circumstances shall vibrators be allowed to come into contact with the reinforcement or formwork nor shall they be withdrawn quickly from the mass of concrete but shall be drawn back slowly so as not to leave voids. Internal type vibrators shall not be placed in the concrete in a random or haphazard manner nor shall concrete be moved from part of the work to another by means of the vibrators.

The duration of vibration shall be limited to that required to produce satisfactory compaction without causing segregation. Vibration shall on no account be continued after water or excess grout has appeared on the surface.

1.30 *Attendance of Steel Fixer and Carpenter*

During the concreting of all reinforced concrete, including prestressed concrete, a competent steel fixer and carpenter shall be in attendance on each concreting gang, to ensure that the reinforcement, formwork and embedded fittings are kept in position as work proceeds.

1.31 *Curing of Concrete*

Concrete shall be cured by protecting the surface from the effects of sunshine, drying winds, frost, rain, running water or mechanical damage for a continuous period of four days when the cement used in the concrete is sulphate-resisting Portland cement, Portland Pulverised-Fuel Ash cement or Portland Blastfurnace Cement. The protection shall be applied as soon as practicable after completion of placing by one or more of the following methods as approved by the S.O.:

- (a) By water sprays in continuous operation;
- (b) By covering with hessian or similar absorbent material, or sand, kept constantly wet;
- (c) After thorough wetting, by covering with a layer of waterproof fabric kept in contact with the concrete surface.

- (d) By the application of an approved non-staining liquid curing membrane which is either self-removing or easily removed following curing period and which has a 75% moisture retention standard. The liquid shall be applied to formed surfaces immediately after stripping the formwork.

Liquid curing membrane (d) shall not be used on Class U1 surfaces where laitance is to be removed and aggregate exposed to provide a satisfactory bond for placing further concrete or mortar screeds or on surfaces where the S.O. is of the opinion that the appearance of the concrete surface will be affected.

1.32 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 further relative movement.

Concrete placed to form the face of a construction joint shall have all laitance removed and the large aggregate exposed prior to the placing of fresh concrete.

The laitance shall wherever practicable be removed when the concrete has set but not hardened by spraying the concrete surface with water under pressure or brushing with a wire brush sufficient to remove the outer mortar skin and expose the large aggregate without being disturbed. Where the laitance cannot be removed due to hardening of the concrete, the whole of the concrete surface forming the joint shall be treated by high pressure water jet, sand blasting, use of a needle gun or a scaling hammer to remove the surface laitance.

Before concreting is resumed, all loose matter on the existing concrete surface shall be removed and the surface slightly wetted.

1.33 Dimensions and Surfaces of Finished Concrete

Workmanship in formwork and concreting shall be such that concrete shall require no making good, surfaces being perfectly compacted, smooth and with no irregularities. Concrete surfaces for the various classes of unformed and formed finishes shall in any event not exceed the maximum permitted tolerance which shall be as shown in the table below except where expressly stated otherwise in the Specification or Drawings.

In the table "line and level" and "dimension" shall mean the lines, levels and cross-sectional dimensions shown on the Drawings.

Surface irregularities shall be classified as "abrupt" or "gradual". Abrupt irregularities include, but shall not be limited to offsets and fins caused by displaced or misplaced formwork, loose knots and other defects in formwork materials, and shall be tested by direct measurement. Gradual irregularities shall be tested by means of a straight, template for plane surfaces or its suitable equivalent for curved surfaces, the template being 3.0 m long for unformed surfaces and 1.5 m long for formed surfaces.

Maximum tolerance (mm) in :

Class of finish	Line and level	Abrupt irregularity	Gradual irregularity	Dimension
U1	+/-12	6	+/-6	-
U2	+/-6	3	+/-3	-
U3	+/-6	3	+/-3	-
F1	+/-12	6	+/-6	+12, -6
F2	+/-6	6	+/-6	+12, -6
F3	+/-3	3	+/-3	+6/-6

1.34 Unformed Surfaces

Finishes to unformed surfaces of concrete shall be classified as U1, U2, U3, spaded' or `bonded concrete' or such other special finish as may be particularly specified. Where the class of finish is not specified, the concrete shall be finished to Class U1.

Class U1 finish is the first stage for Class U2 and U3 finishes and for a bonded concrete surface. Class U2 finish shall be a leveled and screeded, uniform plain or ridged finish, which (unless it is being converted to Class U2, U3 or bonded concrete) shall not be disturbed in any way after the initial set and during the period of curing, surplus concrete being struck off immediately after compaction.

Where a bonded concrete surface is specified, the laitance shall be removed from the Class U1 finish surface and the aggregate exposed while the concrete is still green.

A spaded finish shall be a surface free from voids and brought to a reasonably uniform appearance by the use of shovels as it is placed in the works.

Class U2 finish shall be produced by manual or mechanical floating of the concrete surface after the initial set has taken place and the surface has hardened sufficiently. The concrete shall be worked no more than is necessary to produce a uniform `sandpaper' finish free from screedmarks.

Class U3 finish shall be a hard smooth steel-trowelled finish. Trowelling shall not commence until the moisture film has disappeared and the concrete has hardened sufficiently to prevent excess laitance from being worked into the surface. The surface shall be trowelled under firm pressure and left free from trowel marks.

The addition of dry cement, mortar or water will not be permitted during any of the above operations.

Exposed aggregate finish shall be achieved by exposure of the coarse aggregate using a method approved by S.O. The average depth of exposure shall be 6 mm for concrete with a maximum aggregate size of 20 mm and between 6 mm and 12 mm for concrete with a maximum aggregate size of 40 mm.

The Contractor shall prepare sample panels 1000 mm x 500 mm of concrete with an exposed aggregate finish for inspection and approval by the S.O. at the site.

1.35 Building in Plant and Grouting-in

Wherever possible, pipes and other items of plant passing through concrete structures shall be installed and connected to the remainder of the pipework system to ensure proper fit, and shall be built into the structure as work proceeds.

Where this procedure is impracticable due to programme or other requirements, holes shall be formed for the items of plant to allow them to be built in later after complete installation of the plant.

In no case shall individual pipes of a complicated pipework system including flanged joints be built into concrete structures before accurate fit of the whole system can be checked after the complete installation.

Where holes are formed these shall be of size and shape sufficient to permit proper placing and compaction of concrete or grout. The surfaces of the holes shall be treated to produce a 'bonded' surface before installation of plant.

Before grouting-in commences the plant shall be adequately supported in position to prevent movement or damage during grouting-in.

Concrete used for building-in shall be of the same grade as concrete of the member into which the plant is being built, except that the mix shall also incorporate an approved expanding additive used in accordance with the manufacturer's instructions. Concrete used for water retaining structures shall be non shrink in nature to ensure water tightness. Concrete, mortar and grout shall be carefully placed and compacted around the plant to avoid damaging or moving the plant.

1.36 Structural Pre-Cast Concrete

Structural units of pre-cast concrete shall be manufactured in the grade of concrete and to the sizes and details shown on the Drawings. The concrete shall comply in every aspect with the provisions of the Contract whether such units are manufactured on the site or obtained from other manufacturers.

All cement, aggregate and other materials for pre-cast concrete units with faces which are exposed either internally or externally shall be from the same sources throughout. Exposed surfaces of the units shall be uniform in colour and in texture.

Formwork and unformed surfaces for pre-cast concrete units shall comply with the requirements for F3 formed surfaces and U3 unformed surfaces except that the dimensional variations shall not exceed the values listed below, unless otherwise detailed on the Drawings.

Length	+/-6 mm
Cross-section	+ /6 mm each direction
Straightness	6 mm (deviation from intended line)

Flatness 3 mm (deviation from a 1.5 m straight edge placed in any position on a nominally plane surface)

Squareness when considering the squareness of a corner, the longer of the two adjacent sides being checked shall be taken as the baseline, and the shorter side shall not vary in its distance from the normal so that the differences between the greatest and the shortest dimension exceeds 6 mm. When the nominal angle is other than 90 degrees, the included angle between the check line shall be varied accordingly.

Twist any corner on any nominally plane surface shall not be more than 6 mm from the plane containing the other three corners.

The positions of individual connecting bolts, bolt holes, projecting steel and other devices in any associated group (eg. the joint of two pre-cast units) shall be within 3 mm of their true position in the group in which they are cast. The location of any such group shall be within 6 mm of its true position in the unit in which it is cast, provided that such deviation does not adversely affect the proper assembly of the whole structure.

The Contractor shall submit to the S.O. for approval, full details of his proposed method of carrying out all operations connected with the manufacture and assembly of precast concrete structural members, including :

- ❑ A description of the types of casting bed, mould and formwork for the various types of members;
- ❑ The procedure for concrete casting and the method of curing the concrete;
- ❑ The procedure for transporting, handling, hoisting and placing of each type of pre-cast structural member;
- ❑ Full details of temporary supports necessary to ensure adequate stability during erection, due account be taken of construction loads, including wind.

1.37 Installation of Pre-Cast Concrete Units

At all stages and until completion of the work, pre-cast members shall be adequately protected to preserve all permanently exposed surfaces, arises and architectural features. The protection shall not mark or otherwise disfigure the concrete.

All units shall be laid, bedded, jointed and fixed in accordance with the lines, levels and other details shown on the Drawings.

Dry-pack mortar jointing for packing shall consist of one part of volume ordinary Portland cement and two and half parts by volume of fine aggregate passing a 1 mm sieve. The mortar shall be mixed with only sufficient water to make the materials stick together when being moulded in the hands. The mortar is thoroughly compacted.

Any pre-cast concrete structural member which is found to be cracked, damaged or otherwise inferior in quality either before or after erection shall be rejected and replaced by the Contractor.

1.38 Pr-Stressed Concrete

The Contractor shall submit to the S.O. for approval his proposed method of carrying out all operations connected with pre-stressed concrete work and his proposals for handling, hoisting and placing a position any pre-cast pre-stressed concrete units.

Pre-stressed concrete work whether pre-cast or cast in-situ shall be as detailed on the Drawings and the Contractor shall provide full details of his proposed method of carrying out all operations connected with pre-stressing including :-

- (a) Design of concrete mix
- (b) Description of concrete casting and curing operations
- (c) Procedure for pre-stressing and method of checking and recording the pre-stress, wire extension and anchorage slip.
- (d) Procedure for handling, hoisting and placing of any pre-cast units.
- (e) Grouting of ducts

All tendons, duct forming devices, anchorages and other components shall be kept free of mud, oil (except water soluble oil applied for protection), paint, retarders, loose rust, or other foreign matter. They shall be placed with a tolerance of ± 3 mm in concrete dimensions of 300 mm or less or ± 6 mm in concrete dimensions over 300 mm.

1.39 No-Fines Concrete

No-fines concrete shall be made using a coarse natural aggregate conforming with BS 882 and cement to BS 4027. No fine aggregate shall be used. The grading of the coarse aggregate shall be;

- Not less than 95% by weight passing a 19 mm BS sieve;
- Not more than 5% by weight passing a 10 mm BS sieve.

The proportion of aggregate, cement and water shall be determined by trial mixes by the Contractor starting with a cement : aggregate particles ratio of one to eight by volume.

The trial mix shall be considered suitable when all the aggregate particles are coated with a film of cement grout. The water content shall be just adequate. The concrete when placed shall contain no layers of laitance.

No-fines concrete shall not be mixed by hand.

Vibration shall not be used to compact the concrete. Three test cubes of no-fines concrete shall be made of each trial mix. The minimum crushing strength of the chosen mix shall be 3 N/sq,mm at 28 days.

1.40 Pre-Cast Concrete Products

- (a) Pre-cast concrete products shall where appropriate be constructed in accordance with British Standards as follows, being hydraulically pressed where possible :

Type of Unit	Standard
Concrete blocks	BS 6073 : Pt 1 : 1981
Concrete kerbs, etc.	BS 7261 : Part 1 : 1990
Concrete flags	BS 7263 : Pt 1 : 1990
Concrete sills	BS 5642
Concrete lintels	BS 5977

The concrete shall comply in every aspect with the provisions of the Specification whether such products are manufactured on the site or obtained from other manufacturers.

- (b) Interlocking concrete paving shall include supply and laying of pavers, preparation of surface, supply of sand and casting of edge restraint beams.

The pavers shall comply with the requirement of MA 20, Specification for concrete segmental Paving Units, published by the Concrete Masonry Association of Australia.

1.41 Sampling and Testing of Aggregate

The Contractor shall sample and carry out a mechanical analysis of the fine aggregate and each nominal size of coarse aggregate in use employing the methods described in BS 1881 at least once in each week when concreting is in progress and at such more frequent intervals as the S.O. may require.

The grading of all aggregates shall be within specified limits and should the fraction of aggregate retained on any sieve differ from the corresponding fraction of aggregate in the approved mix by more than 2% of the total quantity of fine and coarse aggregate, S.O may instruct the contractor to alter the relative proportions of the aggregates in the mix to allow for such difference.

1.42 *Sampling and Testing of Concrete*

The Contractor shall provide the equipment necessary to determine the compacting factor of freshly mixed concrete at each place where concrete is being made and shall determine the compacting factor of the freshly mixed concrete by the method described in BS 1881 on each day or as the S.O. may direct.

For each grade concrete, works test cubes shall be made whenever required by the S.O. but not less frequently than as follows unless otherwise particularly specified :-

for concrete of Grades 25, 30, 35A, 40	one set of cubes per 25 cu.m or part thereof concreted per day;
for concrete of Grades 15 or 20	one set of cubes per 50 cu.m or part thereof concreted per day

Each set of cubes (six cubes per set) shall be made from a single sample taken from a randomly selected batch of concrete. Three cubes shall be tested 7 days after manufacture and three cubes 28 days after manufacture.

1.43 *Compliance with Specified Requirements*

The concrete shall be deemed satisfactory provided that :

- (i) The average 28 days strength determined from any group of four consecutive sets of three test cubes exceeds the specified characteristic strength by not less than 7.5 N/sq.mm for Grade 15 concrete and 10 N/sq.mm for Grades 20, 25, 30, 35A and 40.
- (ii) The average of each set of three test cube results is greater than 100% of the specified characteristic strength.

If only one set of three cube results fails to meet the second requirement, those results may be considered to represent only the particular batch of concrete from which the cubes were taken, provided that the average strength of the group satisfies the first requirement.

If more than one set of three cube results in a group fails to meet the second requirement or if the average strength of any group of four consecutive sets of three test cubes fails to meet the first requirement then all the concrete in all the batches represented by all such cubes shall be deemed not to comply with the strength requirements.

1.44 *Non-Compliance*

When the average strength of four sets of three consecutive test cubes fails to meet the first requirement, no further concrete from that mix shall be placed in the work and the contractor shall establish the cause of the failure and apply such remedies as are necessary. The Contractor shall demonstrate by trial mixes and test cube results that the revised mix is in accordance with the specified requirements.

The Contractor shall within 24 hours of the date of test make proposals for agreement with the S.O. about action to be taken in respect of any concrete represented by test cubes which fail to meet either of the requirements. These proposals may include, but shall not be limited to, cutting and testing cores.

Concrete which is ultimately found not to comply with any of the requirements of the Specification shall be rejected and shall be broken out and replaced or otherwise dealt with as agreed with the S.O.

1.45 ***Cutting and Testing of Core Samples***

As and where discussed by the S.O. cylindrical core specimens of 150 mm nominal diameter shall be cut normal to the face of the hardened concrete for the purpose of examination and testing. The procedure for drilling, examination, measurement and testing for compressive strength shall be in accordance with BS 1881. Prior to preparation for testing, the specimen shall be made available for examination by the S.O. If the crushing strength of the specimen determined in accordance with paragraph 114 of BS 1881 is less than the characteristic strength at 28 days for the grade requirements in other respect, the concrete in that part of the works of which it is a sample shall be considered not to comply with the specified requirements.

1.46 ***Inspection Procedures***

Before any concrete is placed, the Contractor shall carry out an inspection to ensure that all preparations are complete, including the provision of the necessary equipment and personnel, and shall ensure that sufficient materials are available to complete the work proposed.

After completion of this inspection the work shall be offered for inspection by the S.O., sufficient time being allowed for inspection and correction of any defects. No concrete shall be placed until the S.O. has inspected and approved the surfaces upon which the concrete is to be placed the formwork and the reinforcing steel.

Where required by the S.O. the Contractor shall institute a 'pour card' system in which a card is made out for each lift of concrete and is initialed by the Contractor and S.O. indicating that the inspections have been carried out.

The 'pour card' shall include spaces to identify the concrete being placed and to signify completion of the inspections by the Contractor and S.O. of the following items:

- Preparation of surface on which concrete is to be placed;
- Formwork;
- Reinforcement;
- Ready for concrete placing;
- Inspection after removal of formwork (any remedial work shall be agreed and noted);

- Curing procedures;
- Completion of remedial work (if any)

1.47 Concrete Protection Systems

Where required all structural concrete in contact with the ground shall be protected by one of the methods specified below. Unless otherwise specified or detailed on the Drawing, in-situ concrete surfaces which are to be protected shall have either U2 or F2 finish as appropriate.

(a) Prefabricated membrane tanking :

The membrane shall be preformed consisting of 1.5 mm thick rubber/bitumen compound formulated for use in hot climates, backed with 0.3 mm thick PVC sheet. The membrane shall adhere with watertight joints to itself at overlaps and to concrete surfaces prepared with suitable priming compound.

The membrane and primer shall be applied in accordance with the manufacturer's instructions to horizontal, inclined and vertical surfaces.

After the blinding concrete has hardened, the membrane shall be applied, bitumen face downwards, and shall extend at least 150 mm beyond the outer limits of the structure. As soon as the membrane has been applied and before any reinforcement or structural concrete is placed, the membrane shall be covered by a sand/cement screed 50 mm thick, extending over the whole area of the base of the structure. The membrane projection of 150 mm shall be temporarily protected with a layer of board as specified below to prevent mechanical damage.

After the concrete structure has been constructed up to ground level and curing is completed, the surfaces which will be in contact with the ground, or as detailed otherwise on the Drawings, shall be primed with the material supplied by the membrane manufacturer. The vertical membrane shall be bonded onto the projection of the base membrane and terminated in a chase at the top. Fillets and reinforcing strips shall be used.

Completed areas of vertical membrane shall be protected from mechanical damage during backfill operations by 12 mm thick cardboard, fibre-board or chipboard secured with suitable adhesive or by concrete block-work.

(b) Made-in-place membrane tanking :

As an alternative to prefabricated membrane taking on horizontal surfaces, the contractor may propose to design, supply and install a made-in-place membrane of bitumen asphalt concrete laid on a tack coat placed on clean original ground.

The bitumen asphalt concrete shall comprise bitumen or asphalt and coarse and fine aggregates.

SYABAS' STANDARD SPECIFICATION FOR PIPE LAYING WOKS

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The Contractor shall demonstrate to the S.O. by testing, by trial and by experience that made-in-place membrane tanking exhibits characteristics which are in all respect equal to or better than prefabricated membrane tanking. The system shall be :-

- ❑ Waterproof during life of protected structure;
- ❑ Robust during preparation for concreting;
- ❑ Durable during life of structure;
- ❑ Flexible in differential settlement;
- ❑ Incompressible under weight of structure.

Made-in-place membrane tanking may be used in place of blinding concrete provided that the contractor shall also have demonstrated to the S.O. the practicability of this system by testing, by trial and by experience.

Vertical or sloping concrete surfaces shall be protected by prefabricated membrane tanking as specified which shall overlap and adhere to made-in-place membrane tanking over a width of 150mm.

The emulsion shall be a rubber-rich bituminous emulsion suitable for use in hot climates and capable of building up a film with minimum dry thickness of 1.0 mm, which is impermeable to water penetration and possessing a high degree of flexibility.

A priming mixture shall be made by thoroughly mixing 1 part emulsion with 6 parts fresh water. Coats other than priming coat shall not be diluted.

Application rates shall be as follows or as necessary to build up a minimum dry film thickness of 1.0mm.:

Surface	Coat	Application rate (sq.mm/litre)
Horizontal	1st (priming)	7
	2 nd	1
	3 rd	1.5
Vertical	1st (priming)	7
	2 nd	2
	3 rd	2
	4 th	2

Over-coating shall take place as soon as the previous coat has dried. Immediately the final coat has been applied to vertical surfaces, bitumenized building paper shall be applied to the fresh emulsion and pressed into close contact over the whole area of the protection.

Horizontal and vertical surfaces shall be protected from mechanical damage during subsequent construction work by screed or boarding as specified for membrane tanking.

(d) Polyethylene sheet

250 micron polyethylene sheet shall be placed against vertical or sloping surfaces of excavated ground before placing concrete directly against such surfaces.

Backfilling with sand against protected surfaces shall be carried out in such a manner that the protection is not damaged. Nevertheless, if such damage occurs, the damage shall be made good to the satisfaction of the S.O.

1.48 Concrete Protection Procedures

Details of concrete protection shall be shown by the contractor on the preliminary working drawings. Such details shall include corners overlaps, brick or board protection and details for curves faces, etc. Concrete protection systems proposed for use in the works shall be demonstrated by the Contractor to the S.O. for approval before submission of preliminary working drawings showing use of such systems in the works.

1.49 Machinery Bases and Closure of pocket

Bases to take machinery and associated pipework shall be constructed in fair faced concrete to the dimensions shown on the approved machinery drawings or as ordered by the S.O. The mounting surface of the base shall be steel floated to true and level planes.

The structural concrete on which the bases are to be erected shall be prepared by hacking and cleaning off.

Bases shall be tied to the structural concrete with vertical reinforcement. Horizontal reinforcement shall also normally be provided at the level of the pockets for the holding down bolts.

Bolt pockets and lead-ins for grout shall be formed by a means which shall have the approval of the S.O. Polystyrene formers will not be permitted. Where expanded metal is used as a former it shall be left in.

When the machinery has been erected the bolt pockets shall on approval of the S.O. be completely filled using a mixture of 2 parts of cement to 3 parts sharp sand by volume with sufficient water to form a thick creamy consistency.

The machinery shall be run under the supervision of the contractor and witnessed by the S.O. after the grout has hardened. When so directed the Contractor shall complete the grouting operation by filling the space between the top of the concrete and the underside of the machinery base plate.

No separate payment will be made for complying with the provision of this clause and all cost shall be deemed to be included elsewhere in the Bill of Quantities.

1.50 Measurement of In-Site Concrete

For concrete placed in-site separate measurements shall be made of plain or mass (i.e. unreinforced) concrete and of reinforced concrete for each of the specified grades of concrete.

In-situ concrete and all work in connection therewith as specified shall be valued by the measurement of only such items as are set forth in the Bill of Quantities. Except where expressly shown to the contrary, formwork (excluding formwork for horizontal construction joints) and steel reinforcement shall be measured separately from and in addition to, measurement of concrete placed in-situ. Measurement of formwork and of steel reinforcement shall be as provided in clauses 2.4.14 and 2.5.12 respectively. Unformed surface finishes class U1, U2 and U3 and spaded finish shall not be measured for payment.

In-situ concrete shall be measured to the limits shown on the Drawings and any concrete placed outside such limits by reason of the Contractor's method of working or due to his carelessness or error and whether it has been permitted by the S.O. or not shall not be measured for payment. In concrete surround to pipes, thrust and anchor blocks and valve chambers a deduction from the measurement shall be made for the volume occupied by the pipes. No deduction from the measurement shall be made in respect of:-

- (i) Any purpose made hole or opening which has an average cross-sectional area less than 1600 sq cm or which has a volume of 0.1 cu metre or less;
- (ii) Any portion of chases, rebates, channels, pipes, ducts or the like whose cross-sectional area in 1000 sq mm or less;
- (iii) Any chamfer 100 mm wide or less on the splay;
- (iv) The space occupied by any steel reinforcement, rails, joints or the like embedded in the concrete.

Building paper or other protection of foundation surfaces, where ordered by the S.O. shall be measured as the net area so protected and no measurement shall be made of laps or joints.

Concrete testing shall be separately measurement only if and to the extent that items for tests are provided in the Bill of Quantities.

1.51 Measurement of Form Opening of Build in Plant

Payment for form opening or build in plant shall be made at the rate per opening tendered. The rate shall include the cost of handling, provision of false work and labour necessary to forming opening or building in at the required position. The rate shall be measured according to the opening size.

1.52 Measurement of Grouting Back The Opening

Payment for grouting back the opening shall be made at the rate per opening tendered. The rate shall include the cost of handling, provision of falsework, labour, material and equipment necessary to complete grout the gap. The grout shall be either ordinary Portland Cement or Non-shrink grout. The rate shall be measured according to the opening size. The work could only be considered complete after it has passes the water tightness test.

1.53 Measurement of Pre-Cast Concrete

Items for pre-cast concrete shall include the manufacture and fixing in the works of the pre-cast units and all works in connection therewith as specified.

Pre-cast concrete shall be measured as fixed in the works by numbers of units, by volume, by area or by length as indicated in the Bill of Quantities. Measurement (except where by numbers) shall include the space occupied by joints between units but not by bedding. Otherwise all measurement shall be net except that no deduction shall be made in respect of any purpose formed hole, duct or the like which has an average cross-sectional area less than 2500 sq.mm.

No separate measurement for payment shall be made in respect of formwork, surface finishes, reinforcement, joggles, dowels, jointing, bedding or the like for pre-cast concrete unless separate items are expressly provided in the Bill of Quantities.

Pre-cast pre-stressed concrete and all work in connection therewith as specified shall be valued by the measurement of only such items as are provided in the Bill of Quantities.

1.54 Sizes and Sequence of Concrete Pours

Before commencing concreting the Contractor shall submit for approval his detailed proposals for the sequence of placing concrete and the positions of vertical and horizontal construction joints. The proposals shall comply with the following :-

Where limitations in lengths of floor or roof slabs that may be cast without joints in any direction are stated on the Drawings, the slabs shall be subdivided by construction joints into panels of dimensions not exceeding the stated limit on length. The panels shall be separately concreted in one continuous operation and no panels shall be concreted until the concrete in adjacent panels is at least 7 days old.

Where limitations in lengths of wall that may be cast without joints are stated on the Drawings they shall be divided into segments not exceeding the stated maximum length by vertical joints which are continuous with the floor joints and extend the full height of the walls in an unbroken alignment. Each segment above the top of the wall haunch and the top of the wall shall be cast in a series of lifts each of a length and height to be approved by the S.O.

Alternate segments in a lift shall be concreted and an interval of 7 days shall elapse before the intervening segments in the same lift are concreted.

At each joint rebates shall be formed to receive sealing compounds as shown on the Drawings.

Each segment of the wall footing and haunch defined by the floor and wall joints shall be concreted in one continuous operation. Segments shall be concreted alternately and an interval of at least 7 days shall elapse before intervening segments are concreted.

1.55 *Cleaning to Water Retaining Structures*

All water retaining structures shall on completion, be carefully cleaned as follows:-

- (a) The structure shall be cleared of all debris and shall be brushed down on all internal faces with a stiff broom while still dry, and all resulting debris removed; all associated reservoir pipework shall be cleaned in accordance with the specification requirements.
- (b) The structure shall then be flooded with approximately 75 mm of clean water and the whole of the internal faces shall be carefully brushed down with stiff brooms, using the water continuously until all faces are clean; the water shall then be drained off, and the walls and floors hosed and flushed with clean water until perfectly clean.

1.56 *Testing of Water Retaining Structures*

As soon as possible after completion of water retaining structures but not before the concrete has attained its specified 28 day strength they shall be tested for water tightness by filling with water up to the designed top water level. The rate of filling shall be reasonably constant and shall not exceed 2 m of depth in 24 hours except in the case of small structures where a higher rate may be allowed by the Contractor. After filling the structure shall be allowed to stand full (being topped up as necessary) for at least 72 hours, for absorption of water by the concrete to take place, at the end of which period the level shall be accurately noted. The structure shall then be tested for a further period of at least 72 hours (48 hours in the case of channels and smaller structures as agreed) and shall be accepted as watertight if :-

- (i) No leaks or damp patches on the backs of walls are discernible during period of the test (if the backs of walls are wetted by rainfall or any other cause the test must be delayed until they are dry for at least 72 hours). In the case of individual parts of a structure being tested independently, the division walls also must be watertight.
- (ii) The floor under drainage system of the structure (if any) remains dry, or the flow in it before the test is not increased as a result of filling the structure with water;
- (iii) The recorded change in level of the water in the structure minus the loss of water by evaporation gives a figure which does not exceed 1/2000 of the depth of water originally in the structure.

During the 72 hour test period referred to above the loss of water by evaporation shall be determined by measurement of the loss of water from a shallow watertight tray of 0.4 sq.m in area containing not less than 75 mm depth of water and positioned to float on the surface of the water in the structure.

The roofs and manhole covers of the closed reservoirs shall be tested for water-tightness before the laying of any roof membrane by general observation from within the reservoir for damp patches or leaks over a period of heavy and prolonged rain but should such a suitable occurrence fail to happen, the roof and fittings shall be hosed down vigorously and this shall be repeated in such a way as to keep the roof wet for 3 successive days.

The roof and fittings shall be deemed satisfactory for water-tightness if there are no discernible leaks or damp patches from inside the reservoir. Remedial measures and retesting shall be carried out at the Contractor's expense until satisfactory.

Should any parts of the structure fail the above tests in any respect, the Contractor shall immediately take steps to ascertain the nature and positions of any defects or leakages, shall empty the structure, and remedy the defects in an approved manner. Note that a damp patch appearing on the outside of the wall must be rectified from the water face, a repair making the outer face only watertight shall not be approved; this applies to bobbin holes also.

When the remedial work has been completed in an approved manner, the testing and if necessary rectification shall be repeated until a satisfactory test is achieved.

If necessary, in extreme cases of lack of water-tightness, the structure or any member or section of a member thereof may be rejected.

Any expense in materials (including the supply of water), plant labour and all other costs including overheads and profit involved in the satisfactory water-tightness testing of all the water retaining structures in the works shall be included in the rates entered by the Contractor in the Bill of Quantities.

Any costs, incurred by the Contractor in remedial or replacement work necessary to achieve the satisfactory testing shall be entirely at the expense of the Contractor.

1.57 Disinfection of Water Retaining Structures

Disinfection of water retaining structures shall be carried out by the Contractor after these structures have passed the water-tightness test.

The structure shall be emptied. The internal surfaces of the walls, the internal surface of the roof, the internal and external surfaces of all pipes and specials inside the structure, and all other surfaces inside the structure shall be vigorously brushed and flushed with jets of clear, clean water until all foreign materials, dirt and grit which may have accumulated thereon are removed. All water and material accumulated in the cleaning operation shall be discharged or otherwise removed from the structure.

The Contractor shall provide evidence to the satisfaction of the S.O. that the chlorine dosage proposed for sterilisation will not adversely affect joint sealant materials.

Chlorination shall be carried out by Method 1 or Method 2 as set out below. The Contractor shall submit details of his proposed method of working to the S.O. for approval before commencing disinfection of any structure.

Method 1

The structure shall then be filled to the overflow level with potable water to which enough chlorine is added to provide a free chlorine residual throughout the structure of not less than 10 mg/l at the end of the appropriate retention period. This shall be not less than 6 hours when the water entering the structure has been chlorinated uniformly by gas-feed equipment or chemical pump or not less than 24 hours when the structure has been filled with water which has been mixed with calcium hypochlorite or sodium hypochlorite within the structure. The procedure set out in AWWA C652 shall be followed.

At the end of the retention period the free chlorine residual shall be reduced to not more than 2 mg/l by draining and refilling or blending with potable water having a low chlorine concentration, after which the water within the structure shall be sampled to determine the free chlorine residual and for bacteriological analysis to check for the absence of coliform organisms of faecal origin. If the results are unsatisfactory the structure shall be drained and the disinfection procedure shall be repeated. The costs of any re-testing shall be borne by the Contractor.

Method 2

A solution of 200 mg/l available chlorine shall be applied directly to all surfaces of the structure which would come into contact with water by suitable brushes or spray equipment. The disinfected surfaces shall remain in contact with the strong chlorine solution for at least 30 minutes after which potable water shall be admitted and the structure shall be filled and tested for bacteriological quality as in Method 1.

1.58 Chlorine Bearing Solution/Mixture for Disinfection

The chlorine bearing solution/mixture shall be prepared using clear, clean water and chlorine, either as liquid chlorine, calcium hypochlorite or sodium hypochlorite.

Liquid chlorine shall be introduced into the water filling the structure to give a uniform concentration during the entire filling operation. Portable chlorination equipment shall be carefully operated and shall include a liquid chlorine cylinder, gas flow chlorinator, chlorine ejector, safety equipment and an appropriate solution tube to inject the high concentration chlorine solution into the filling water. The solution tube shall be inserted through an appropriate valve located on the inlet

pipe and near the structure so that the chlorine solution will mix readily with the inflowing water.

Calcium hypochlorite granules, broken to a size not exceeding 0.6 mm maximum dimension, may be poured into the structure from an opening or placed inside on dry surfaces prior to the introduction of flowing water. They shall be so positioned that a current of water circulating around the structure shall dissolve them during the filling operation.

Sodium hypochlorite shall be applied to the water entering the structure by means of a chemical feed pump, or shall be applied by hand-pouring into the structure and allowing the inflowing water to provide the desired mixing.

1.59 Sealing Compounds

Sealing compounds for horizontal construction joints shall be hot applied bituminous sealants complying with the requirements of BS 6213. Sealing compounds for vertical and inclined construction joints shall be bituminous putty of a quality approved by the S.O.'s Representative. Both sealing compounds shall be capable of expanding to 110% of their original thickness between parallel faces without separation.

Horizontal floor joints and vertical and inclined joints to be filled with the sealing compound shall first be thoroughly cleaned and dried and an approved primer compatible with the sealing compound shall be applied. Each primer and sealing compound shall be applied in accordance with the manufacturer's recommendations for tropical climates.

Sealing compounds for expansion and contraction joints shall be polyurethane or polysulphide liquid polymer sealants complying with BS 6213 obtained from approved manufacturers. The sealing compound shall be capable of expanding to 133% of its original thickness between parallel faces without extruding and of contracting to 67% of its original thickness without separation.

Expansion and contraction joints to be filled with the sealing compound shall first be thoroughly cleaned and dried and an approved primer compatible with the sealing compound shall be applied. Both primer and sealing compound shall be applied in accordance with the manufacturer's recommendations for tropical climates.

1.60 Joint Fillers

Joint filler shall either cork joint filler or cellular joint filler.

Cork joint filler shall be waterproof and rotproof and shall not extrude as a result of compression. Cork joint filler shall compress to less than 50% of its original thickness with immediate recovery to 80% or more of its original thickness.

Cellular joint filler shall be preformed low-compression joint filler made from foam rubber. Cellular joint filler shall recover to its original thickness after each loading and unloading.

1.61 Waterstops

Waterstops shall be of rubber or PVC and shall be of a type and manufacture approved by the S.O. The Contractor shall carefully follow the manufacturer's instructions in any work involving the incorporation of waterstops into structures.

Waterstops shall be fully continuous when laid and site joints shall be limited to simple butt joints which are to be made with the manufacturer's fusing jig. A careful check shall be made on all joints after completion to ensure that no imperfections exist.

Waterstops shall be securely held in position by the formwork or by means to be approved by the S.O. and the concrete shall be carefully worked around the waterstops to ensure that they are completely embedded and that no air pockets will exist.

1.62 Movement Joints

Movement joints are defined as all joints intended to accommodate relative movement between adjoining parts of a structure, special provision being made where necessary for maintaining the water tightness of the joint. The Contractor shall comply with the instructions of manufacturers of proprietary jointing materials and shall, if required by the S.O., demonstrate that the jointing materials can be applied satisfactorily.

The Contractor shall submit to the S.O. for his approval, as soon as practicable after the acceptance of his Tender and not less than three weeks before the commencement of concreting, details of his proposals for the installation of waterstops. 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 waterstops. Where it is agreed with the S.O. that it is necessary to make an intersection or change of direction or any joint. Other than a butt joint in a straight run, on Site, a prefabricated joint intersection or change of direction piece shall be made and submitted to such tests as the S.O. may require.

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

The surface of set concrete in a movement joint shall, where specified on the Drawings, be painted with two coats of bituminous paint and fresh concrete shall be placed against it only when the paint is dry. Expansion joints shall be formed by a separating strip of approved preformed joint filler.

Caulking grooves shall be provided as shown on the Drawings. At all joints where a caulking groove is formed, immediately prior to caulking, the groove shall be wire brushed and loose material removed and blown out by compressed air. After the groove has dried it shall be primed and caulked with approved jointing compound applied in accordance with the manufacturer's instructions. At all caulked joints, the face of the caulking strip and 25 mm width of concrete on either side shall be painted with two coats of paint having the same base as the caulking compound.

1.63 Structural Tests

The S.O. may, if required, call for loading test on the structure, and for floors, roofs and similar structures. The test load shall be up to 1½ times the design superimposed load for the areas to be tested. The test load shall not be applied within 84 days of the casting of the appropriate concrete, and temporary timber supports, in case of failing, must be immediately available. The test shall be satisfactory if upon removal of that load the residual deflection does not exceed one quarter of the maximum deflection after 24 hours loading. If the residual deflection exceeds this amount, the test is to be repeated and if residual deflection is as above, this may be considered satisfactory. All measurements and levels of the second test are to be entirely independent of the first test.

The S.O. may deem tests necessary because :-

- (a) Site made test cubes failed to attain specified strengths.
- (b) Shuttering was prematurely removed.
- (c) Overloading occurred during stages of construction or while concrete was immature.
- (d) Concrete was improperly cured.
- (e) Any other circumstances attributed to alleged negligence by the Contractor.
- (f) Any other reason.

If the loading test be made wholly or in part for reason (a), the test shall be at Contractor's own cost; if for reason (b) to (e) inclusive, then if the test be satisfactory the Contractor shall be reimbursed for the cost of the test; if for reason (f) Contractor shall make the test and be reimbursed for the cost of same, whatever the test result.

If the result of the loading test be unsatisfactory the S.O. may instruct that the part of the works concerned be taken down or removed and reconstructed to comply with this Specification, or that such remedial measures shall be taken as to make the works secure. If the test was made for one or more of the reasons (a) to (e) inclusive, as detailed above, the Contractor shall take down or remove and reconstruct the works or take such remedial measures as the S.O. may instruct, all at his own cost.