GENERAL SPECIFICATIONS FOR CONCRETE WORKS

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1 GENERAL

1.1 SCOPE OF SECTION

This section covers formwork, reinforcement, concrete and joints in the concrete required in the Permanent Works.

Formwork constitutes formwork, falsework and void formers required for the placing of concrete.

Reinforcement constitutes plain and deformed bar reinforcement and steel fabric to be cast into concrete but does not include prestressing tendons or any other embedded steel.

Concrete constitutes concrete and mortar other than special concretes and mortars specified in other sections of the Specification.

A list of applicable international standards is included under Sub-Section 7 of this specification.

1.2 SUBMISSIONS TO THE ENGINEER

The Contractor shall submit to the Engineer all documents etc. as required by the relevant clauses of the Conditions of Contract. With regard concrete works, the submissions are in particular two copies of each of the following:

- shop drawings, details and calculations
- reinforcement detail drawings
- bar bending schedules.

2 FORMWORK

2.1 DEFINITIONS

Formwork means the surface against which concrete is placed to form a face, together with all the immediate supports to retain it in position while concrete is placed.

Falsework means the structural elements supporting both the formwork and the concrete until the concrete becomes self-supporting.

A formed face is one which has been cast against formwork.

An exposed face is one which will remain visible when construction has been completed.

2.2 CONSTRUCTION OF FORMWORK AND FALSEWORK

The design, provision and maintenance of all falsework shall be the responsibility of the Contractor and shall be in accordance with BS 5268 and BS 5975. When requested, he shall provide a design analysis for particular parts of the work and erection shall not commence until he has received the written permission of the Engineer. Notwithstanding any approval given or implied or comments made, design shall remain the responsibility of the Contractor.

Whether or not a design analysis has been requested, before construction begins the Contractor shall submit to the Engineer drawings showing details of the proposed formwork and falsework including void formers where required.

Formwork and falsework shall be so constructed that they will support the loads imposed on them by the fresh concrete together with additional loads imposed by vibrating equipment and by construction traffic, so that after the concrete has hardened the formed faces shall be in the positions shown on the Drawings within the tolerances set out in Sub-Section 2.5.3.

Ground supports shall be properly founded on footings designed to prevent settlement.

Joints in formwork for exposed faces shall, unless otherwise specified, be evenly spaced and horizontal or vertical and shall be continuous or form a regular pattern.

All joints in formwork including formwork for construction joints shall be tight against the escape of cement and fines. Where reinforcement projects through formwork, the form shall fit closely round the bars.

Formwork shall be so designed that it may be easily removed from the work without damage to the faces of the concrete. It shall also incorporate provisions for making minor adjustments in position, if required, to ensure the correct location of concrete faces. Due allowance shall be made in the position of all formwork for movement and settlement under the weight of fresh concrete.

Where overhangs in formwork occur, means shall be provided to permit the escape of air and to ensure that the space is filled completely with fully compacted concrete.

Formwork shall be provided for concrete surfaces at slopes of 30° to the horizontal or steeper. Surfaces at slopes less than 20° may be formed by screeding. Surfaces at slopes between 20° and 30° shall generally be formed unless the Contractor can demonstrate to the satisfaction of the Engineer that such slopes can be screeded with the use of special screed boards to hold the concrete in place during vibration.

Horizontal or inclined formwork to the upper surface of concrete shall be adequately secured against uplift due to the pressure of fresh concrete. Formwork to voids within the body of the concrete shall also be tied down or otherwise secured against floating.

The internal and external angles on concrete surfaces shall be formed with fillets and chamfers of 25 x 25 mm unless otherwise shown on the Drawings. Tops of lifts shall have a 20 x 20 mm grout check set true to line, to present a neat joint when the next lift is placed.

Supports for formwork may be bolted to previously placed concrete provided the type of bolt used is acceptable to the Engineer. If metal ties through the concrete are used in conjunction with bolts, the metal left in shall not be closer than 50 mm to the face of the concrete.

Removable tapered plugs shall be used against the formwork when casting in all metal ties through the concrete where the surface finishes is Class F3 or higher.

Formwork shall not be re-used after it has suffered damage which is sufficient to impair the finished surfaces of the concrete.

Where circumstances prevent easy access within the form for cleaning and inspection, temporary openings for this purpose shall be provided through the formwork.

Shear keys shall be provided in all vertical battered or sloping contraction or construction joints of the size and shape indicated on the Drawings.

Where precast concrete elements are specified for use as permanent formwork, or proposed by the Contractor and agreed by the Engineer, they shall comply with the requirements of Sub-Section 5 of the Specification. Such elements shall be set true to line and level within the tolerances prescribed for the appropriate class of finish in Sub-Section 2.5.3 and fixed so that they cannot move when concrete is placed against them.

2.3 PREPARATION OF FORMWORK

Before any reinforcement is placed into position within formwork, the latter shall be thoroughly cleaned and then dressed with a release agent. The agent shall be either a suitable oil incorporating a wetting agent, an emulsion of water suspended in oil or a low viscosity oil containing chemical agents. The Contractor shall not use an emulsion of oil suspended in water nor any release agent which causes staining or discoloration of the concrete, air holes on the concrete surface, or retards the set of the concrete.

In order to avoid color differences on adjacent concrete surfaces, only one type of release agent shall be used in any one section of the Works.

In cases where it is necessary to fix reinforcement before placing formwork, all surface preparation of formwork shall be carried out before it is placed into position. The Contractor shall not allow reinforcement or pre-stressing tendons to be contaminated with formwork release agent.

Before placing concrete all dirt, construction debris and other foreign matter shall be removed completely from within the placing area.

Before concrete placing commences, all wedges and other adjusting devices shall be secured against movement during concrete placing and the Contractor shall maintain a watch on the formwork during placing to ensure that no movement occurs.

2.4 REMOVAL OF FORMWORK

Formwork shall be carefully removed without shock or disturbance to the concrete. No formwork shall be removed until the concrete has gained sufficient strength to withstand safely any stresses to which it may thereby be subjected.

Formwork may be removed when the concrete has attained the strength set out in the following table, where 'C' is the characteristic strength used for design purposes for a given class of concrete, provided that the attained strength is determined by making test cubes and curing them under the same conditions as the concrete to which they refer.

Position of Formwork	Strength to be Attained
Vertical or near vertical faces of reinforced walls, beams and columns	0.3 C
Underside of arches, beams and slabs (formwork only)	0.5 C
Supports to underside of arches, beams and slabs	1.0 C
Arched linings in tunnels and underground works	3 N/mm^2

Alternatively the stripping times required to achieve the strengths in the table above for the anticipated range of ambient temperatures shall be agreed in advance by the Contractor and Engineer for each class of concrete.

Compliance with these requirements shall not relieve the Contractor of his obligation to delay removal of formwork until the removal can be completed without damage to the concrete. The Contractor will be held responsible for and shall make good at his cost all injury and damage arising from the premature stripping of formwork.

If the Contractor wishes to strip formwork from the underside of arches beams and slabs before the expiry of the period for supports set out above, it shall be designed so that it can

be removed without disturbing the supports. The Contractor shall not remove supports temporarily for the purpose of stripping formwork and subsequently replace them.

As soon as the formwork has been removed, any allowable remedial measures to the surfaces shall be carried out as specified below. Bolt holes in concrete faces other than construction joints which are not required for subsequent operations shall be completely filled with mortar sufficiently dry to prevent any slumping at the face. The mortar shall be mixed in the same proportions as the fine aggregate and cement in the surrounding concrete and with the same materials and shall be finished flush with the face of the concrete.

2.5 FORMED SURFACE FINISHES

2.5.1 Classes of Finish

The surface finish to be achieved on formed concrete surfaces shall be as shown on the Drawings and defined hereunder. The selection of materials for the formwork, the design of the formwork and its fixing shall be such as to achieve the required surface finish without any subsequent remedial work.

Classes of unformed free surface finishes are defined in Sub-Section 4.11.

Class F1 Finish: This finish is for surfaces against which backfill or further concrete will be placed. Unless specifically directed otherwise, formwork may be sawn boards, sheet metal or any other suitable material which will prevent the loss of fine material from the concrete being placed.

Class F2 Finish: This finish is for surfaces which are permanently exposed to view. Forms to provide a Class F2 finish shall be faced with wrought tongued and grooved boards with square edges arranged in a uniform pattern and close jointed or with suitable sheet material. The thickness of boards or sheets shall be such that there shall be no visible deflection under the pressure exerted by the concrete placed against them. Joints between boards or panels shall be horizontal and vertical unless otherwise directed. This finish shall be such as to require no general filling of surface pitting, but fins, surface discoloration and other minor defects shall be remedied by methods agreed by the Engineer.

Class F3 Finish: This finish is for surfaces which will be in contact with flowing water, for tunnel lining, for reservoirs, and for surfaces prominently exposed to view where good appearance is of special importance. To achieve this finish, which shall be free of board marks, the formwork shall be faced with plywood complying with BS 1088 or equivalent material in large sheets. The sheets shall be arranged in an approved uniform pattern. Wherever possible, joints between sheets shall be arranged to coincide with architectural features or changes in direction of the surface. All joints between panels shall be vertical and horizontal unless otherwise directed. Suitable joints shall be provided between sheets to maintain accurate alignment in the plane of the sheets. Unfaced wrought boarding or standard steel panels will not be permitted for Class F3 finish. The Contractor shall ensure that the surface is protected from rust marks, spillages and stains of all kinds.

Class F4 Finish: This finish is similar to that required for F3 but is used in places where a first class alignment and a particularly dense surface free from air holes and other defects is required, suitable for the application of decorative finishes and at locations which will be in contact with water flowing at high velocities and/or through significant curvatures.

The Contractor's attention is drawn to the fact that this finish requires careful selection of materials and the highest quality of workmanship and supervision at all stages. A proprietary formwork lining membrane may be appropriate to aid the achievement of this class of finish.

2.5.2 Curved Surfaces

For curved surfaces where F2, F3 or F4 finishes are called for the formwork face shall be built up of splines cut to make a tight surface which shall then be dressed to produce the required finish.

Alternatively single curvature surfaces may be faced with plastic or plywood linings attached to the backing with adhesive or with escutcheon pins driven flush. Linings shall not bulge, wrinkle or otherwise deform when subjected to temperature and moisture changes.

2.5.3 Tolerances

All parts of formed concrete surfaces shall be within the tolerances set out in the following table:

Class of Finish	Tolerances in mm (see Note 1)		
	A	B	C
F1	10	10	+ 25 to - 10
F2	5	10	+ 15 to - 10
F3	2	5	+ 10 to - 10
F4	Nil (see Note 2)	2	+ 5 to - 5

Notes:

1. The tolerances A, B and C given in the table are defined as follows:
   - 'A' is an abrupt irregularity in the surface due to misaligned formwork or defects in the face of the formwork;
   - 'B' is a gradual deviation from a plane surface as indicated by a straightedge 3 m long. In the case of curved surfaces the straightedge shall be replaced by a correctly shaped template;
   - 'C' is the amount by which the whole or part of a concrete face is displaced from the correct position shown on the Drawings.

2. Abrupt irregularities are not permitted in an F4 finish. Any residual irregularities which remain after removal of formwork shall be removed by grinding to achieve a transition of 1 in 50 between the surfaces adjacent to the irregularity.
3. Where a surface lies in the vertical plane, the maximum deviation from true vertically shall not be greater than 2mm per meter vertical height.

In cases where the Drawings call for tolerances other than those given in the table above, the Drawings shall have precedence.

Where precast units have been set to a specified tolerance, further adjustments shall be made as necessary to produce a satisfactory straight or curved line. When the Engineer has approved the alignment, the Contractor shall fix the units so that there is no possibility of further movement.

2.6 REMEDIAL WORK TO DEFECTIVE SURFACES

2.6.1 Minor Defects

a. General

This clause covers the remedial work required to repair defects of a non-structural nature. The repair of defects of a structural nature such as honeycombing extending to reinforcement, lack of bond on construction surfaces, shrinkages, cracks etc. are covered in Sub-Section 2.6.2.

Prior to undertaking permanent work, the Contractor shall submit details of all proposed methods of repairing surface blemishes and shall, where required by the Engineer, carry out trials on test panels to prove the adequacy of the proposed methods and competence of the workmen.

Immediately after the removal of the shuttering, the Contractor shall inspect the concrete and shall report any defects to the Engineer. All repair work on such defects and the timing of such repairs shall be agreed by the Engineer prior to the work being done. The repair work shall be carried out by skilled workmen only, and shall be completed to the satisfaction of the Engineer.

Generally where repairs are required, they shall be carried out immediately after forms have been stripped. Proprietary bonding agents acceptable to the Engineer shall be used where repairs are made on concrete which is older than 7 days.

No plastering of surfaces will be permitted unless specifically stated or ordered. If surfaces are not true to shape due to inaccurate formwork or poor placing or any other cause whatsoever, the Engineer may order the removal of the whole of the section and its reconstruction.

b. Repairs

Surface defects such as small areas of honeycombing, cavities produced by form ties, large isolated blow holes, broken corner edges, etc. shall be repaired with mortar consisting of cement and sand in the same ratio as that of the concrete being repaired. The materials used shall be of the same type and from the same source as those used in the production of the concrete and if necessary a pigment shall be added to the mortar in order to obtain a color match with the concrete.

Surfaces to be repaired shall be thoroughly cleaned of loose particles and laitance before applying the mortar.

All repaired surfaces shall be cured as specified for that structure or as agreed by the Engineer.

Where the concrete has been damaged by adhesion of the concrete to the formwork panel, the cracked and loose concrete shall be removed or where lifting of the fresh concrete at construction joints has occurred, the crack shall be scraped out immediately on both sides of the wall to a depth of at least 50 mm. The cavities so formed shall thereafter be repaired as described above.

Surface irregularities which are outside the limits of tolerance A set out in the table in Sub-Section 2.5.3 shall be ground down in the manner and to the extent instructed by the Engineer.

Defects other than those mentioned above shall be dealt with as agreed by the Engineer.

c. Rubbing of Surface

If the finish of exposed formed surfaces does not comply with the requirements for uniformity of texture, appearance and color, the Contractor shall rub down the exposed surfaces of the entire structure or any part thereof as specified below.

The surface shall be saturated with water for at least one hour. Initial rubbing shall be carried out with a medium coarse carborundum stone, using a small amount of mortar, consisting of cement and sand in the same ratio as that of the concrete being rubbed down, on the face. Rubbing shall be continued until all form marks, projections and irregularities are removed and a uniform surface is obtained. The final rubbing shall be carried out with a fine carborundum stone and water. This rubbing shall continue until the entire surface is of a smooth, even texture and is uniform in color. Thereafter the surface shall be washed with a brush to remove surplus paste and powder.

Where the concrete surfaces formed by sliding formwork require treatment in order to achieve the surface finish specified for the member, the concrete shall, as soon as the surfaces are exposed under the formwork, be floated with rubber-lined floats to the desired finish.

2.6.2 Major Defects

a. General

Concrete damaged by improper curing, traffic or any other cause or any concrete which is honeycombed or has interstices or is not homogeneous or which is not true to dimensions, or the surface finish defects fall outside those covered by Sub-Section 2.6.1, may be classed as defective work. Such defective work shall be removed and the Contractor shall replace it with acceptable concrete of specified strength without any additional payment.

If on stripping any formwork the concrete surface is found to be defective in any way, the Contractor shall submit to the Engineer his proposal for remedying the defects and shall make no attempt to remedy such defects prior to the Engineer's inspection and the receipt of the Engineer's agreement to his proposal.

In assessing the Contractor's proposals for remedying any defects the Engineer may request further investigation into the integrity of the concrete. Such investigations shall be carried out by the Contractor at no additional payment. On completion of his assessment the Engineer shall either accept or reject the Contractor's proposal. In the case of the latter the work referred to shall deemed to be not acceptable and shall be removed together with any subsequent permanent works that may have been placed and such removal is necessary to effect the reconstruction of the defective work.

Defects other than those mentioned below shall be dealt with as agreed by the Engineer.

b. Honeycombed and Porous Concrete

In all structures, honeycombed and porous concrete shall be cut out fully to sound concrete or as otherwise agreed by the Engineer, but the depth of cut out shall not be less than 100 mm or 25 mm clear distance behind reinforcement whichever is the greater.

On exposed surfaces the perimeter of the repair shall be neatly defined by disc cuts not less than 25 mm deep. The cavity shall have roughened sides at least 75 mm in depth for the full perimeter and the sides of the cavity shall be splayed back to form a dovetail.

After cleaning out with water and compressed air, a thin layer of cement grout or a proprietary bonding agent approved by the Engineer shall be brushed on the concrete surfaces in the cavity and it shall then be filled immediately with concrete of the same class as the main body but with aggregate larger than 20 mm nominal size removed, or as otherwise directed by the Engineer. A form shall be used against the cavity, provided with a lip to enable concrete to be placed. The form shall be filled to a point above the top edge of the cavity.

The concrete shall contain the minimum quantity of water to reduce shrinkage as much as possible and shall be thoroughly vibrated into place. Afterwards the lip of concrete shall be broken off and the surface made good. If instructed by the Engineer, suitable shrinkage reducing agents or other additives shall be used.

When required by the Engineer, the Contractor shall drill and grout in injection pipes for subsequent grouting of any remaining voids.

Where acceptable to the Engineer, honeycombed concrete may be grouted with an epoxy grout of suitable viscosity for penetrating all voids.

Where repairs are to be made with concrete, they shall be carried out as soon as possible to achieve the best bond between the repair and the parent concrete. If repairs are delayed longer than 7 days after concreting a suitable wet to dry epoxy bonding agent shall be used.

All epoxy materials shall be used strictly in accordance with the manufacturer's instructions.

2.6.3 Cracked Concrete

Surface cracks having a width equal or greater than 2 mm shall be pressure grouted using appropriate chemical or epoxy grouts applied strictly in accordance with the manufacturer's instructions.

3 REINFORCEMENT

3.1 MATERIALS

In general the reinforcement used in the permanent works shall be either Grade 425, deformed high yield steel bars or Grade 250, plain round mild steel bars to BS 4449. Other types of reinforcement may be required in certain areas as shown on the drawings or agreed with the Engineer. All reinforcement shall comply with the appropriate British Standards, which include the following:

- BS 4449 for hot rolled plain bar and high yield deformed bar
- BS 4482 for hard drawn mild steel wire
- BS 4483 for steel mesh fabric

All reinforcement for use in the Permanent Works shall be tested for compliance with the appropriate British Standard in a laboratory acceptable to the Engineer and two copies of each test certificate shall be supplied to the Engineer. The frequency of testing shall be as set out in the British Standard.

In addition to the testing requirements described above, the Contractor shall carry out additional tests as instructed by the Engineer.

Any reinforcement which does not comply with the Specification shall be removed from Site.

All mechanical couplers used shall be subject to the approval of the Engineer.

For all mechanical couplers proposed the Contractor shall submit to the Engineer test certificates from a recognized testing authority certifying that the tensile and other properties of the couplers comply with the appropriate British Standards or equivalent standards as approved by the Engineer.

3.2 STORAGE OF 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. All reinforcement which has become corroded or pitted to an extent which, in the opinion of the Engineer, will affect its properties shall be removed from Site.

3.3 CUTTING AND BENDING REINFORCEMENT

The Contractor shall cut reinforcement to length and bend it to the shape shown on the schedules within the dimensional tolerances given in BS 8666. Bars shall be bent cold by the application of slow steady pressure. No flame cutting of high yield bars shall be permitted, except where approved by the Engineer. Hooks or right angle bends shall be formed where

called for by the schedules and to the dimensions and tolerances specified in BS 8666. At temperatures below 5°C the rate of bending shall be reduced if necessary to prevent fracture of the steel.

After bending, bars shall be securely tied together in bundles or groups and legibly labelled as set out in BS 8666.

Reinforcement shall be thoroughly cleaned and all dirt, scale, loose rust, oil and other contaminants removed before it is placed in the Permanent Works.

3.4 FIXING REINFORCEMENT

Reinforcement shall be securely fixed in position within a dimensional tolerance of 20 mm in any direction parallel to a concrete face and within a tolerance of 5 mm at right angles to a face, provided that the cover is not thereby decreased below the minimum shown on the Drawings.

Unless otherwise agreed by the Engineer, all intersecting bars shall either be tied together with 1.6 mm diameter soft annealed iron wire and the ends of the wire turned into the body of the concrete, or shall be secured with a wire clip of a type agreed by the Engineer.

Spacer blocks shall be used for ensuring that the correct cover is maintained on the reinforcement. Blocks shall be as small as practicable and of a shape agreed by the Engineer. They shall be made from dense concrete of the same materials as the member in which they are located, but using 10 mm aggregate and cured in accordance with Sub-Section 4. They shall have 1.6 mm diameter soft annealed iron wire embedded in them to facilitate their fixing to the reinforcement.

Alternatively another type of spacer block may be used subject to the Engineer's agreement.

Reinforcement shall be rigidly fixed so that no movement can occur during concrete placing. The Contractor shall provide for all stools and other fixing materials/bars required for the support of the reinforcement. Any fixings made to the formwork shall not be within the space to be occupied by the concrete being currently placed.

On no account shall reinforcing steel be used as a means of support for shuttering or scaffolding and the steel shall be kept entirely free from strain while concrete is being placed.

No splices shall be made in the reinforcement except where shown on the Working Drawings or agreed by the Engineer.

Reinforcement shall not be welded except where required by the Contract or agreed by the Engineer. If welding is employed, the procedures shall be as set out in BS 2640 for gas welding or BS 7123 for metal arc welding. Full strength butt welds shall only be used for steel complying with BS 4449, and if used on high yield deformed bars complying with BS 4449 the permissible stresses in the vicinity of the weld shall be reduced to those applicable to plain bars complying with that specification.

The quality and strength of welding will be assessed by destructive laboratory testing of samples selected by the Engineer.

Mechanical splices shall not be used unless the Engineer agrees otherwise.

The Contractor shall ensure that reinforcement left exposed in the Permanent Works shall not suffer distortion, displacement or other damage. When it is necessary to bend protruding reinforcement aside temporarily, the internal radius of the bend shall not be less than four times the bar diameter for plain bars or six times the bar diameter for high yield bars. Such bends shall be carefully straightened before concrete placing continues, without leaving residual kinks or damaging the concrete round them.

High tensile bars shall not be bent after placing in the Works.

Before concrete is placed in any section of the Permanent Works which includes reinforcement, the reinforcement shall be completely clean and free from all contamination including concrete which may have been deposited on it from previous operations.

In members that are formed with sliding formwork, spacer "ladders" for the placing and fixing of the wall reinforcement shall be used at spacing agreed with the Engineer. The ties shall be spaced at multiples of the horizontal spacing of the horizontal bar spacing in the wall, and be used to secure the horizontal reinforcement. The laps in the horizontal reinforcement shall be staggered to ensure that no part of two laps in any four consecutive layers lie in the same vertical plane.

Where holes are to be drilled subsequently, the Contractor shall ensure that the reinforcement is placed clear of the corridor required for drilling and shall mark the location of the hole by attaching a suitable former to the shutter.

3.5 COVER TO REINFORCEMENT

The concrete cover to reinforcement shall be equal to or greater than the cover stated in the general notes accompanying the Drawings, or indicated on the Drawings but shall not be less than 10 mm greater than the nominal maximum size of the aggregate.

When directed, the Contractor shall measure the cover to all reinforcement with a cover meter as soon as the formwork has been stripped and submit the record of this survey to the Engineer as soon as practical.

Where cover meters show cover less than specified above the work shall be rectified to the satisfaction of the Engineer.

The Contractor shall, in addition, provide on site two portable electronic cover meters for the sole use of the Engineer. The Contractor shall recalibrate these cover meters weekly on a test section of the concrete containing the full range of reinforcement used on site set at known depths. The cover meters shall be capable of accurately measuring covers 25 mm greater than the greatest minimum cover specified.

Precast concrete members with inadequate cover shall be rejected and removed from Site.

4 CONCRETE

All aspects of concrete to be provided for the Permanent Works shall be in accordance with EN 206 and BS 8110.

4.1 DEFINITIONS

Structural concrete is any class of concrete which is used in reinforced, unreinforced or prestressed concrete construction.

Non-structural concrete is composed of materials complying with the specification which is used only for filling voids and for similar purposes.

No fines concrete is composed of cement and of aggregates sized between 40 mm and 12 mm only.

Shotcrete (sprayed concrete) is an intimate mixture of cement, aggregates, water and (if applicable) additives, shot into place by means of compressed air through a spray nozzle.

Rebound is defined as the constituents of shotcrete that rebound from the surfaces during the application of shotcrete.

A formed surface is a face which has been cast against formwork.

A free surface is a horizontal or nearly horizontal surface produced by screeding or troweling to the level and finish required.

A pour refers to the operation of placing concrete into any mould, bay or formwork, etc., and also to the volume which has to be filled. Pours in vertical succession are also referred to as lifts.

Water:cement ratio is the ratio of the weight of the free water in the mix to the weight of cement content in the mix. Free water is the water in the mix excluding water absorbed by the aggregate.

Characteristic strength means the specified 28 day cube strength (150 mm cubes) below which not more than 5% of the test results may be expected to fail.

4.2 MATERIALS FOR CONCRETE

4.2.1 General

The Contractor shall submit to the Engineer full details of all materials which he proposes to use for making concrete not less than 30 days before he proposes to commence batching of Trial Mixes specified in Sub-Section 4.3 and shall provide samples of the proposed materials as directed by the Engineer. No concrete shall be placed in the Permanent Works until the Engineer has approved the materials of which it is composed. Approved materials shall not thereafter be altered or replaced by other materials without the consent of the Engineer.

The Contractor shall ensure that the sources of supply are sufficient to meet the quantities and rates of supply required to comply with the Contractor's programme.

In the event that any source of supply has to be changed for any reason, the tests and trial mixes shall be repeated.

4.2.2 Requirements for Cements

The term ‘cement’ means Portland Cement (Pc) or, subject to the prior approval of the Engineer, a combination of Pc and ground granulated blast furnace slag (g.g.b.s) in accordance with BS 6699 or pulverized fuel ashes (p.f.a.) in accordance with BS 3892, unless otherwise stated.

Ordinary Portland Cement used in the works shall comply with the requirements of EN 197 and shall come from a single source of supply.

Admixtures shall only be used on the written approval of the Engineer.

Should low alkali Portland Cement be called for, the cement shall not contain more than 0.6% by weight of alkali measured as sodium and potassium oxides and expressed as the "equivalent sodium oxide content".

If approved by the Engineer for use in water retaining structures, the target mean proportion of g.g.b.s. shall not exceed 50% and the target mean proportion of p.f.a. shall not exceed 35%. This applies to blended cement and combinations made at the mixer.

4.2.3 Transporting, Storing and Testing of Cement

Bulk cement shall be transported to the Site in watertight containers built and equipped for the purpose, and shall be stored on Site in weatherproof silos.

Bagged cement shall be transported to Site in vehicles provided with effective means of ensuring that it is protected from weather. Cement in bags shall be stored in a suitable weatherproof structure of which the interior shall be dry and well ventilated at all times. The floor shall be raised above the surrounding ground level and shall be so constructed that no moisture rises through it. Each delivery of cement in bags shall be stacked together in one place; the height of the stack shall at no time exceed 3 meters. The bags shall be closely stacked so as to reduce air circulation and shall not be stacked against an outside wall. Different types of cement in bags shall be clearly distinguished by visible markings and shall be stored in separate stacks. Cement from broken bags shall not be used in the Permanent Works.

The Contractor shall store at the Site sufficient cement so that construction of the Works is not delayed and at least sufficient for the programmed requirements for the succeeding three weeks. In arranging his storage facilities he shall take into account all factors which might cause delays in the supply of cement such as the manufacturer's capacity, time for transport to the Site, holidays, weather conditions and breakdowns. Cement shall be used in the same chronological order as that in which it is delivered to Site.

Cement which has become hardened or lumpy or fails to comply with the Specification in any way shall be removed from the Site.

All cement used in the Permanent Works shall be tested by the manufacturer or the Contractor at the laboratory on Site or at another laboratory acceptable to the Engineer. The tests shall be in accordance with BS 4550 and EN 196, and the Contractor shall supply two copies of each test certificate to the Engineer. The requirements for acceptance of cement are as follows:

- Specific surface : not less than 225 m²/kg
- Chemical composition : within the limits set out in BS EN 197
- Minimum mortar cube strengths : 23 N/mm2 after 3 days
  41 N/mm2 after 28 days
- Setting time: initial : not less than 45 minutes
  final : not more than 10 hours
- Soundness : expansion not more than 10 mm
- Heat of hydration (if required) : not more than 250 kJ/kg at 7 days
  not more than 290 kJ/kg at 28 days

Each set of tests carried out by the manufacturer or Contractor shall relate to not more than one day's output of each plant, and shall be made on samples taken from cement which is subsequently delivered to the Site. Alternatively, subject to the agreement of the Engineer, the frequency of testing shall be one set of tests for every 200 tons of cement delivered to Site from each plant.

Cement which is stored on Site for longer than two months shall be retested in a laboratory acceptable to the Engineer at the rate of one set of tests for every 200 tons, and at monthly intervals thereafter.

Cement which does not comply with the Specification shall not be used in the Permanent Works.

The temperature of the cement shall at no time be permitted to exceed 50°C.

The Contractor shall keep full records of all data relevant to the manufacture, delivery, testing and use of all cement used in the Permanent Works and shall provide the Engineer with two copies thereof.

4.2.4 Aggregates for Concrete

The Contractor is free to obtain aggregates from any source.

Aggregates for concrete shall conform to the requirements for fine and coarse aggregates in BS 882 and EN 12620. Fine and coarse aggregates shall separately conform to the requirements set out below.

a. General Requirements

Aggregate shall be clean, hard, durable and frost resistant and shall not contain iron pyrites, iron oxides (other than magnetite), mica, shale, coal or other laminar, soft or porous materials.

b. Gradings:

Fine aggregate shall conform to BS 882 Table 4, Zones C or M. In order to achieve an acceptable grading it may be necessary to blend materials from more than one source. Coarse aggregates shall be supplied in the nominal sizes specified and shall be graded in accordance with BS 882 for single sized aggregates. A coarse aggregate shall be predominantly angular, rounded or irregular as defined in BS 812: Part 1.

c. Chlorides:

The chloride content shall not exceed 0.03% by weight expressed as chloride ion when tested in accordance with BS 812 subject to the further restriction on total chloride content hereunder.

d. Sulphates:

The sulphate content shall not exceed 0.4 per cent by weight expressed as SO3 when tested in accordance with BS 812: Part 118 subject to the further restriction on total sulphate hereunder.

e. Total Chloride and Sulphate Content:

The total chloride content arising from all ingredients in a mix including cement, water and admixtures shall not exceed the following limits, expressed as chloride ion and as a percentage of the weight of cement in the mix:

- for prestressed concrete, steam cured concrete or concrete containing sulphate resisting or supersulphated cement: 0.05%;
- for any other reinforced concrete 0.3% in 95% of all test results providing no result is more than 0.5%.

The total sulphate content expressed as SO3 of all the ingredients in a mix including cement, water and admixtures shall not exceed 4.0% of the weight of cement in the mix.

f. Soundness:

After testing using the procedure set out in BS 812: Part 121, aggregates shall not show a weight loss of more than 18 per cent.

g. Alkali Reactive Minerals:

No part of the aggregates shall contain any mineral known to have a potential to cause alkali silica, alkali silicate, alkali carbonate or any other damaging chemical reaction between alkalis and aggregates. The minerals present should be determined by ASTM C294 on a range of samples selected to include every mineral type present in the aggregate as a whole

irrespective of the proportion of the mineral. The reactivity of the minerals shall be assessed by ASTM Test Designation C289 and BS 812: Part 106.

If during the course of the test it is concluded that the presence of a potentially reactive mineral cannot be discounted and that an unequivocal identification of a potentially reactive mineral is not possible, alternative tests shall be carried out such as to provide the required identification.

If the presence of a potentially reactive material cannot be discounted then either

- a low alkali Portland cement shall be used, or
- the reactive alkali of the mix as assessed in accordance with BS EN 206 or BS 5328: Part 4 and expressed as sodium oxide equivalent, (Na2O)e, shall not exceed 3.0 kg/m3.

h. Flakiness:

Flakiness Index of coarse aggregates when tested in accordance with BS 812 shall be as set out hereunder and not as given in BS 882 Table 1:

- for nominal 40 mm aggregate and above: not more than 40;
- for nominal 20 mm aggregate and below: not more than 35.

i. Water Absorption:

The coarse aggregate shall not have a water absorption of more than 2.5 per cent and fine aggregates shall have an absorption of not more than 3% when tested as set out in BS 812 or BS EN 1097: Part 6.

j. Organic Impurities:

Fine aggregate shall be tested as set out in BS 1377: Part 3 and rejected if the percentage of organic matter exceeds 1 per cent.

k. Shrinkage:

Aggregates for structural concrete shall have an intrinsic shrinkage value such that shrinkage of the resultant concrete shall not be greater than 0.05% when tested in accordance with BRE Digest No. 35, Second Series (***Building Research Station, Garston, Watford WD2 7JR. England***), Shrinkage of Natural Aggregates in Concrete.

l. Thermal Properties:

Coarse aggregates used for water retaining structures shall have a low coefficient of thermal expansion.

4.2.5 Aggregates for Mortar

Aggregates for mortar shall conform to BS 1200.

4.2.6 Aggregates for Pavement Concrete

Aggregates for pavement concrete shall comply with the requirements of this Section.

4.2.7 Testing Aggregate

a. Acceptance Testing

The Contractor shall deliver to the Engineer samples containing not less than 50 kg of any aggregate which he proposes to use in the Permanent Works and shall supply such further samples as the Engineer may require. Each sample shall be clearly labelled to show its origin and shall be accompanied by all the information called for in BS 882 and EN 12620.

Tests to determine compliance of the aggregates with all the requirements of Sub-Sections 4.2.4, 4.2.5 or 4.2.6 shall be carried out by the Contractor in a laboratory acceptable to the Engineer. If the tested materials fail to comply with the Specification, further tests shall be made in the presence of the Contractor and the Engineer and acceptability of the material shall be based on such tests.

The acceptance tests carried out by the Contractor shall generally be on three representative samples of fine and coarse aggregates taken in the presence of the Engineer. Total numbers of tests required for acceptance are as follows:

Test	Fine Aggregates	Coarse Aggregates
Water absorption	-	3 *
Flakiness Index	-	3 *
Shell content determination	-	3 *
Test for shell content (where required)	-	1
10% fines test or aggregate Impact Value	_	3 *
Gradings	3 *	3 on each nominal size
Chloride content	3 *	3 *
Sulphate content	3 *	3 *
Soundness	-	3 *
Petrographic examination	as required (minimum 3)	as required (minimum 3)
Clay, silt and dust determination	3	3
Organic impurities	3	3

** One test on each sample*

If at any time a significant physical or chemical change in the nature of the coarse or fine aggregate occurs, or a new source of aggregate is used, the Engineer may direct that some or all of the acceptance testing is repeated.

b. Routine Testing

The Contractor shall carry out routine testing of aggregates for compliance with the Specification during the period in which concrete is being produced for the Permanent Works. The tests set out below shall be performed on aggregates from each separate source

on the basis of one set of tests for each 250 tonnes of fine aggregate or more than 500 tonnes of coarse aggregate, provided also that the aggregates are of uniform quality. If the aggregate from any source is variable, the frequency of testing shall be as instructed by the Engineer.

- Grading: BS 812 or EN 933: Part 2
- Silt and clay content: BS 812 or EN 932
- Moisture content: BS 812 or EN 109 : Part 5

Check on organic impurities: A 350 cc graduated bottle filled to the 120 cc mark with the aggregate sample, and a 3 percent solution of sodium hydroxide in water added to bring the total volume of aggregate plus liquid after shaking to 200 cc. The bottle is stoppered and allowed to stand for 24 hours. If after 24 hours the color of the solution is no darker than pale brown the aggregate tested may be deemed satisfactory.

In addition to the above routine tests, the Contractor shall carry out the following tests at the frequencies stated:

Moisture content: As frequently as may be required in order to control the water content of the concrete as required by the Specification.

Chloride content: As frequently as may be required to ensure that the proportion of chlorides in the aggregates does not exceed the limit stated in the Specification.

The Contractor shall take account of the fact that when the chloride content is variable it may be necessary to test every load in order to prevent excessive amounts of chloride contaminating the concrete. For this purpose the Contractor shall use the Quantab rapid field test. In the event of disagreement regarding the results of the field test, the chloride content of the aggregate shall be determined in the laboratory as described in BS 812 (the Volhard test).

4.2.8 Delivery and Storage of Aggregates

Aggregates shall be delivered to Site in clean and suitable vehicles. Different types or sizes of aggregate shall not be delivered in one vehicle.

Each type or size of aggregate shall be stored in a separate bin or compartment having a base such that contamination of the aggregate is prevented. Dividing walls between bins shall be substantial and continuous so that no mixing of types or sizes occurs.

The storage of aggregates shall be arranged so that as far as possible rapid drying out in hot weather is prevented in order to avoid sudden fluctuations in water content. Storage of fine aggregates shall be arranged so that they can drain sufficiently before use in order to prevent fluctuations in water content of the concrete.

4.2.9 Water for Concrete and Mortar

Water for mixing or curing concrete or mortar shall not contain more than the following concentrations of impurities:

	max ppm
• Sum of sulphates, alkali carbonates and bicarbonates	1000
• Chlorides	500
• Suspended solids	2000
• Other dissolved solid	2000

At the commencement of the Works the Contractor shall send a sample of the water proposed for concrete and mortar to an accredited laboratory capable of carrying out the full analysis of potable water in accordance with either the "Analysis of Raw, Potable and Waste Waters" published by Her Majesty's Stationery Office (HMSO) or "The Standard Method of Examination of Water and Waste Waters" published by the American Water Works Association (AWWA). The results of the analysis shall be submitted to the Engineer. The sample of water sent for analysis shall be taken in the presence of the Engineer. If the water selected comes from a reliable potable water source the Contractor shall obtain a copy of a recent analysis from the chemist of the Water Authority. If the Engineer considers this satisfactory the tests required above need not be carried out.

The water shall be retested at intervals of one month initially until sufficient results are available to determine the suitability of the source. The frequency of testing may then be reduced.

If the source of water is changed it shall be tested as above. If the water contains in excess of 80 per cent of the maximum concentration of any of impurities given above it shall be retested at intervals of not more than two months or as directed by the Engineer.

4.2.10 Admixtures

The use of admixtures in concrete may be required under the Contract to promote special properties to the concrete or may be proposed by the Contractor to assist compliance with the Specification.

If the Contractor proposes to use admixtures he shall submit to the Engineer full details of the admixture he proposes to use and the manner in which he proposes to add it to the mix. The information provided shall include:

i. The typical dosage and the detrimental effects of an excess or deficiency in the dosage.

ii. The chemical names of the main active ingredients in the admixture.

iii. Whether or not the admixture contains chlorides, and if so the chloride ion content expressed as a percentage by weight of admixture.

iv. Whether the admixture leads to the entrainment of air when used at the manufacturer's recommended dosage, and if so, the extent to which it does so.

v. Long and short term effects of the admixture on concrete including the effects on different types of cement and aggregates.

vi. Storage life.

vii. Safety precautions required in handling.

viii. Compatibility with other additives.

ix. Compliance with Standards.

The chloride ion content of any admixture shall not exceed 2% by weight of the admixture nor 0.03% by weight of the cement in the mix.

Admixtures shall not be mixed together without the consent of the Engineer.

Admixtures shall comply with BS EN 480 and shall not have any adverse effect on the properties of the concrete.

4.3 DESIGN OF CONCRETE MIXES

4.3.1 Classes of Concrete

Concrete classes are shown on the Drawings in the style: A/B

where: A = 28 days characteristic strength (N/mm²)
B = maximum aggregate size

The grading may be followed by the suffices:

NF = No Fines
NS = Non-Structural

Concrete classes are shown alternatively by designation of anticipated usage. The grades of concrete mix that shall be used in the works are set out in the table in Sub-Section 4.3.2.

4.3.2 Design of Proposed Mixes

The Contractor shall design the mixes which he proposes to use in the Permanent Works to achieve homogenous durable concrete which will have the required strength, and other criteria specified and which will achieve acceptable workability and resistance to segregation during handling and placing. The proposed mixes shall also comply with the following requirements:

i. The aggregate portion shall be well graded from the nominal maximum size of stone down to 150 micron size.

ii. The cement contents shall not be less than that shown in the table below.

iii. The maximum cement content will not exceed 400 kg/m3.

iv. The water:cement ratio shall be the minimum consistent with adequate workability but in any case not greater than that shown in the table below.

v. The workability shall be consistent with ease of placing and proper compaction having regard to the presence of reinforcement and embedded items, and the proposed method of placing.

vi. The Contractor shall take into account the requirement for temperature control of massive concrete elements or units. Massive elements are defined by a reference

thickness tr = 2A/C, where A is the cross sectional area of the element and C its circumference. Elements are considered massive if tr exceeds 0.5 m.

vii. The "required compressive strength" of cubes crushed on site at 28 days shall be determined by adding to the control strength a figure equivalent to 1.65 x the standard deviation of the cube results (for a permitted 5% failure rate). Until such time as sufficient cubes or at least 40 cubes sampled in a period of not less than 6 days have been tested to enable the standard deviation to be determined statistically, the concrete mix shall be designed so that the average cube strength is greater than the control strength by at least 12 N/mm2. A value not less that 6 N/mm2 may be employed if data of the plant, the materials and the operatives are available from previous use to justify this margin until such time as specific information is available from the site operations.

Where the maximum size aggregate is 40 mm or less, the control strength shall be the characteristic strength. Where the maximum size aggregate is 75 mm the control strength shall be the characteristic strength multiplied by the factors defined in Sub-Section 4.3.3.

viii. The drying shrinkage determined in accordance with BS 1881 or EN 12390 shall not be greater than 0.05%.

ix. Plastic shrinkage shall be limited such that cracking does not occur along reinforcement with minimum cover.

x. For water retaining structures and reservoirs, the minimum cement content shall be 325 kg/m3. A maximum water/cement ratio of 0.55 shall be used except when Portland pulverized-fuel ash cement or a combination of ordinary Portland cement and p.f.a. is used, in which case the water/cement ratio shall be 0.50. The 28-day characteristic cube strength shall not be less than 35 N/mm2, and the concrete shall be classed as Class 35/20. Plasticizers may be used to reduce water:cement ratios.

Where cements containing p.f.a. are used, the maximum permissible cement content may be increased to 450 kg/m3.

xi. For tunnel lining, where pumping of the concrete is approved by the Engineer, the concrete mix to be pumped shall be so designed that ¬

- Slump will not exceed 125 mm;
- Graded aggregate and suitable admixtures be used, wherever necessary, with a view to improving the pumpability of the mix; and
- Its shrinkage capacity shall not be excessively higher than that of ordinary concrete mixes.

Class	Characteristic Strength (N/mm^2)	MSA (mm)	Min[m] Cement Content (kg/m^3)	Maximum Water:Cement Ratio	Anticipated Usage
15/40	15	40			Fill Concrete
20/20	20	20	270	0.65	Blinding
25/20	25	20	280	0.60	Non water-retaining structures
35/20	35	20	325	0.55	Water retaining structures (without p.f.a.)
40/20	40	20	350	0.50	Precast concrete

NS : Non Structural Concrete as Specified in Sub-Section 4.17
NF : No Fines Concrete as Specified in Sub-Section 4.17

The Contractor shall submit to the Engineer full details of all the mixes he proposes to use not less than 30 days prior to the production of trial mixes. The details to be submitted shall include as a minimum the following:

(i) aggregate source

(ii) proportions of aggregate sizes

(iii) cement content, including extender

(iv) aggregate:cement and water:cement ratios

(v) batch quantities

(vi) additives

(vii) workability

(viii) flakiness index of aggregates

(ix) estimated standard deviation

(x) target strength

(xi) mixing time.

4.3.3 Trial Mixes

Not less than 28 days before the date on which the Contractor proposes to use a mix in the Permanent Works, he shall in the presence of a representative of the Engineer prepare six separate batches to the full capacity of the mixer of the proposed mix on separate days, using the materials, plant and equipment which will be used for the Permanent Works. He

shall take sufficient samples from each batch to prepare twelve standard 150 mm test cubes in accordance with EN 12390: Part 1.

If the proposed mixes contain admixtures to improve workability the Contractor shall prepare identical trial mixes omitting the admixture if so instructed by the Engineer in order to determine the effect of the admixture.

If the mix satisfies the requirements of Sub-Section 4.3.2 (v) to the satisfaction of the Engineer, the average slump obtained for each class shall be adopted as the target slump for that grade of concrete.

Three of the cubes from each batch of twelve shall be tested for crushing strength at seven days and six more from each batch at 28 days, all in accordance with EN 12390. The remaining three cubes from each batch shall be tested as instructed by the Engineer.

The density of all the cubes shall be determined before the cubes are crushed.

The average value of the crushing strength of the thirty-six cubes tested at 28 days shall not be less than the "required compressive strength" of cubes as defined in Sub-Section 4.3.2 (vii) for the class of concrete tested.

If the 28 day strength as defined above is less than the required compression strength the mix shall be adjusted in order to comply. If adjustment of aggregate proportions does not increase the strength the water cement ratio shall be reduced. An increase in cementitious content will not normally be acceptable.

In order to save time and expense, initial trials on any mix may be carried out using cubes tested at 7 days where a relationship between 7 day and 28 day strengths has been agreed between the Contractor and the Engineer. The final results of the trials would nevertheless still have to be confirmed by 28 day cube results.

The Contractor shall carry out tests to determine the drying shrinkage of the concrete.

Based on the results of the tests on the trial mixes, the Contractor shall submit full details of his proposals for mix design to the Engineer, including the type and source of each ingredient, the proposed proportions of each mix and the results of the tests on the trial mixes.

If required by the Engineer, the Contractor shall place not less than one cubic metre of any trial mix into formwork prepared to simulate conditions which will apply during construction of the Permanent Works, including reinforcement if appropriate, and using the plant and equipment which he proposes to use for the Permanent Works.

The timing for the removal of formwork shall be in accordance with Sub-Section 2.4. and the concrete surfaces inspected jointly by the Contractor and the Engineer.

If the Engineer does not agree to a proposed concrete mix for any reason, the Contractor shall amend his proposals and carry out further trial mixes. No mix shall be used in the Permanent Works without the written consent of the Engineer.

If the properties of the concrete or of the constituent materials vary during concrete production, the Engineer may require further trial mixes to be made.

The Contractor shall arrange for supplying concrete, making, transporting, curing and testing test cubes and recording the test results which shall be submitted to the Engineer in accordance with Sub-Section 4.15 for both trial mixes and quality control of concrete production unless stated otherwise.

4.3.4 Quality Control of Concrete Production

For each class of concrete in production at each plant for use in the Permanent Works, samples of concrete shall be taken at the point of mixing or of deposition as instructed by the Engineer and in the presence of a representative of the Engineer, all in accordance with the sampling procedures described in EN 12390.

Samples shall be taken on the basis of one for each 100 m3 of concrete placed but in any case not less than one sample per day or one sample for each pour of more than 10 m3 concrete placed, whichever is the more frequent, for each class of concrete produced.

The slump of each sample carried out in accordance with EN 12390 shall be determined at the time of sampling. The slump of each batch of concrete shall similarly be determined.

The concrete shall be deemed to comply with the workability requirements if the slump is within ± 20% of the target slump established from the trial mixes.

Six test cubes shall be cast from each sample and cured as set out in EN 12390: Part 2. Additional cubes as instructed by the Engineer shall be made for testing at ages more than 28 days.

Three cubes shall be tested at 7 days and three at 28 days. The average strength of the three cubes crushed at 28 days shall be referred to as one test result.

Concrete shall be deemed to comply with the strength specified if:

i. no more than 3 test results from any set of 40 consecutive test results fall below the specified control strength;
ii. the average of any 6 successive test results for the same class of concrete is not less than the specified control strength plus 3 N/mm2;
iii. no single cube result is less than the specified control strength minus 3 N/mm² for that class of concrete.

4.3.5 Failure to Comply with Requirements

The Contractor shall undertake such action as the Engineer may consider appropriate to remedy concrete which fails to comply with the Specification. Such action may include but is not necessarily confined to the following:

i. adjusting the mix proportions until the concrete again complies with the Specification;
ii. cutting test cores from the failed concrete and testing in accordance with BS 1881;
iii. full scale load tests or sonic investigations;

iv. carrying out additional works to overcome the effect of the failed concrete;

v. removing the failed concrete;

vi. increasing the frequency of sampling until control is again established.

4.4 MIXING CONCRETE

4.4.1 Equipment

Before any equipment for batching, mixing, transporting, placing, compacting and finishing concrete is ordered or delivered to Site, the Contractor shall submit to the Engineer full details including drawings of all the equipment which he proposes to use and the arrangements he proposes to make.

4.4.2 Batching of Materials for Concrete

Unless otherwise authorized by the Engineer, the quantities of material for each batch of concrete shall be measured separately by weight. The batching plant shall be suitable for weighing out, for any particular batch of concrete, the aggregate, cement and water in quantities up to half the weight of cement if required and any approved admixtures. Apparatus shall be included to record automatically, within an accuracy of plus or minus one per cent, the weight of cement used in the production of each mix of concrete.

The blades of pan mixers shall be maintained within the tolerances specified by the manufacturer of the mixer and the blades shall be replaced when it is no longer possible to maintain the tolerances by adjustment.

The bins for storage of concrete constituents in the batching plant shall be of a self-cleaning type and shall be drawn down until they are practically empty at least three times per week. Aggregate of nominal size 40 mm and larger shall be deposited in the storage bins in a way to avoid separation. Those bins used for storing sand shall be fitted with drainage outlets to prevent the build up of free water in the bottom of the bins. The weighing hoppers shall be constructed so as to permit the convenient removal of overweight material in excess of the prescribed tolerances. The equipment for cement handling shall be constructed so as to minimise the release of dust during operation.

The quantity of water to be added to each batch shall be automatically adjusted to compensate for the variation in moisture content of the coarse and fine sands. The sand bins shall be covered. The readings of percentage moisture content shall be integrated with the weight of sand to give the quantity of water contained in the sand. This quantity shall be automatically fed into a water meter, clearly visible to the batching plant operator, which has been preset with the total quantity of water required for each class of mix. The water meter shall also be linked with the control valve feeding water into the mixer so that when the total quantity of water has been introduced into the mixer the control valve is automatically closed. The water supply circuit shall be fitted with safety devices to prevent spillage or leakage of extra water into the mixer.

Provision for the dispensing of approved admixtures shall include means for obtaining uniform dispersion into the concrete. Admixtures in liquid form shall be discharged into the mixing water and admixtures in powder form shall be discharged concurrently with the cement.

The constituents of each batch shall be weighed within an accuracy of plus or minus one per cent for cement and water and concrete admixture, plus or minus two per cent for fine aggregates and coarse aggregates up to and including 40 mm in size, and plus or minus three per cent for coarse aggregate of larger size.

Convenient facilities shall be provided for readily obtaining representative samples of cement, admixtures, sand and each class of coarse aggregate between the supply bins and the mixers.

The facilities shall also include means for obtaining representative samples of concrete at the point of discharge of each mixer.

The Contractor shall provide standard test weights, at least equivalent to the maximum working load used on the most heavily loaded scale, and other auxiliary equipment required for checking the satisfactory operation of each scale or other measuring device. Tests of the weighing mechanisms shall be carried out in the presence and to the approval of the Engineer. The Contractor shall furnish the Engineer with copies in duplicate of the complete results of the tests and shall make such adjustments, repairs or replacements as the Engineer may consider necessary to ensure satisfactory performance.

The plant shall be arranged in a way which will permit the inspection and checking of all operations by one person. The box containing the levers and/or weights of the weighing scales of the batching plant shall be locked and the keys shall be kept by the Engineer's Representative.

At intervals decided by the Engineer, but which will normally be not less frequently than once per day, the Contractor shall carry out tests by a method agreed by the Engineer to determine the free moisture content of the aggregates. Based on these tests, adjustments shall be made to the quantity of water added to the mix to maintain the approved water/cement ratio.

The Contractor shall prepare a mix content record for each mix showing show the following information:

- class of concrete and mix designation
- quantities of cements, fine aggregates, coarse aggregates, water and additives in each mix
- the location to which the mix is to be sent
- the truck or skip number used to move the concrete
- the numbers of mixes in each truck or skip.

One copy of the record for each truck or skip load shall be delivered to the location where the concrete is to be placed and handed to the Engineers Representative.

A second copy of the record shall be delivered to the Engineer daily on the day following the date of mixing.

4.4.3 Mixing Procedures

Concrete mixing machines shall be capable of producing a uniform distribution of the ingredients throughout the mass.

The mixing operation shall be under the control of a suitably experienced supervisor. Automatic operations shall not be interfered with by operators. The sequence of filling a mixer with the concrete ingredients shall be subject to the agreement of the Engineer and, unless otherwise authorized, the same sequence of filling shall be followed throughout the work. The quantity of mixed material per batch shall not exceed the manufacturer's rated capacity of the mixer.

The period of mixing shall be measured from the time when all the materials except the full amount of water are in the drum until the commencement of discharge. An automatic timing device shall be used to set the duration of mixing, which shall not be less than the values given in the following table:

Mixer Capacity	Mixing Time
1.5 m^3 or less	1.5 minutes
Exceeding 1.5 m^3 but not exceeding 2.5 m^3	2.0 minutes
Exceeding 2.5 m^3 but not exceeding 3.5 m^3	2.5 minutes
Exceeding 3.5 m^3	Time to be agreed by the Engineer

In addition, mixing shall continue for at least one minute after all the water required has been admitted.

The nominal drum or pan capacity of the mixer shall not be exceeded. The speed of rotation of a mixer shall be that recommended by the manufacturer of the machine. Each mixer shall be equipped with an automatic recorder of the number of batches mixed.

After the concrete has been mixed no subsequent addition of water shall be made in the course of concreting.

Mixers which have been out of use for more than 30 minutes shall be thoroughly cleaned before any fresh concrete is mixed.

4.5 TRANSPORT OF CONCRETE

The concrete shall be discharged from the mixer and transported to the Works by means which shall prevent adulteration, segregation or loss of ingredients, and which shall ensure that the concrete is of the required workability at the point and time of placing. The loss of slump between discharge from the mixer and placing shall not exceed 25 mm. Primary control of slump will be at the point of deposition of the concrete in the Works.

Should the Contractor wish to pump concrete to any section of the Works, then he shall satisfy the Engineer regarding his proposals, which shall include the provision of such spare items of plant necessary to avoid delays due to mechanical breakdown. If the Contractor wishes to vary the agreed design mix proportions in order to permit concrete to be placed by pumping, then details of his revised mix design shall be submitted to the Engineer and trial mixes prepared in accordance with this Specification. Precautions shall be taken to avoid depositing water or grout in the Works during starting-up operations or in flushing or clearing of the pipeline. The concrete shall pass through the pipeline in not more than 20 minutes.

The time elapsing between mixing and placing a batch of concrete shall be as short as practicable and in any case no longer than will permit completion of placing and compaction before the onset of initial set. If the placing of any batch of concrete is delayed beyond this period, the concrete shall not be placed in the Permanent Works.

4.6 PLACING OF CONCRETE

4.6.1 Consent for Placing

Concrete shall not be placed in any part of the Permanent Works until the Engineer's consent has been given in writing, and the Contractor shall give the Engineer at least 18 hours notice of his intention to place concrete.

When all preparatory work for a proposed pour has been completed, the Contractor shall request the Engineer's written consent to commence concrete placing at a specified time not less than three hours after making the request.

If concrete placing is not commenced within 24 hours of the Engineer's consent, the Contractor shall again request written consent as specified above.

4.6.2 Preparation of Surfaces to Receive Concrete

Excavated surfaces on which concrete is to be deposited shall be prepared as set out in Sub-Section 6.4.1 of the Specification.

Existing concrete surfaces shall be prepared as set out in Sub-Section 4.12. Before deposition of further concrete they shall be clean, hard and sound and if required by the Engineer shall be wet but without any freestanding water.

Any flow of water into an excavation shall be diverted through proper side drains to a sump, or be removed by other suitable methods which will avoid washing away the freshly deposited concrete or any of its constituents. Any underdrains constructed for this purpose

shall be completely grouted up when they are no longer required by a method agreed by the Engineer.

If so instructed by the Engineer, surfaces against which concrete is to be placed shall receive a prior coating of mortar complying with Sub-Section 4.16. or microcrete mixed in the proportions similar to those of the fines portion in the concrete to be placed. The mortar or microcrete shall be kept ahead of the concrete and shall be well worked into all parts of the excavated surfaces and shall be not less than 5 mm thick.

If any fissures have been cleaned out as described in Sub-Section 6.4.1 of the Specification, they shall be filled with the mortar or with concrete as instructed by the Engineer.

The amount of mortar or microcrete placed at any one time shall be limited so that it does not dry out or set before being covered with concrete.

4.6.3 Placing Procedures

The concrete shall be deposited as nearly as possible in its final position. It shall be placed so as to avoid segregation of the concrete and displacement of the reinforcement, other embedded items, or formwork. It shall be brought up in layers approximately parallel to the construction joint planes and not exceeding 500 mm in compacted thickness unless otherwise permitted or instructed by the Engineer, but the layers shall not be less than four times the maximum nominal size of aggregate in thickness.

Layers shall not be placed so that they form feather edges nor shall they be placed on a previous layer which has taken its initial set. In order to comply with this requirement, a layer may be started before completion of the preceding layer.

All the concrete in a single bay or pour shall be placed as a continuous operation. It shall be carefully worked round all obstructions, irregularities in the foundations and the like so that all parts are completely full of compacted concrete with no segregation or honeycombing. It shall also be carefully worked round and between waterstops, reinforcement, embedded steelwork and similar items which protrude above the surface of the completed pour.

Placing of concrete in continuous walls of water retaining structures shall commence at convenient points on the perimeter of the wall and shall proceed in both directions simultaneously until the ends of the lift unite at intermediate points between the commencement points such that fresh concrete from one direction meets fresh concrete from the other direction. The Contractor's plant and organization on Site shall be sufficient to ensure that a lift of 500 mm in compacted thickness can be poured for the full circumference of the structure in a continuous operation not exceeding 10 hours in duration.

All work shall be completed on each batch of concrete before its initial set commences and thereafter the concrete shall not be disturbed before it has set hard. No concrete that has partially hardened during transit shall be used in the Permanent Works and the transport of concrete from the mixer to the point of placing shall be such that this requirement can be complied with.

Concrete shall not be placed during rain which is sufficiently heavy or prolonged to wash mortar from coarse aggregate on the exposed faces of fresh concrete. Means shall be provided to remove any water accumulating on the surface of the placed concrete. Concrete shall not be deposited into such accumulations of water.

During periods when wind is liable to accelerate the drying of exposed concrete surfaces, covers shall be provided for all fresh concrete surfaces which are not being worked on. Water shall not be added to concrete for any reason.

When concrete is discharged above its place of final deposition, segregation shall be prevented by the use of chutes, downpipes, trunking, baffles or other appropriate devices. Unless otherwise agreed by the Engineer concrete shall not be allowed to fall freely through a height greater than 1.2 meters.

When placing concrete round galleries and other places of difficult access, the Contractor shall take particular care to ensure that the equipment used and the method of its operation is such that the concrete is placed without segregation. Special care shall also be taken during vibration of the concrete to ensure that all irregularities in the rock surfaces are completely filled. Placing equipment shall only be operated by experienced workmen.

Forms for walls, columns and other thin sections of significant height shall be provided with openings or other devices that will permit the concrete to be placed in a manner that will prevent segregation and accumulations of hardened concrete on the formwork or reinforcement above the level of the placed concrete.

When it is necessary to place concrete under water the Contractor shall submit to the Engineer his proposals, which shall conform to the recommendations of BS 8004, for the method and equipment to be employed. The concrete shall be deposited either by bottom-discharging watertight containers or through funnel-shaped hoppers which are kept continuously full with concrete up to a level above the water and which shall have the discharging bottom fitted with a trapdoor and immersed in the concrete in order to reduce to a minimum the contact of the concrete with the water. Special care shall be taken to avoid segregation.

If the concrete in a hopper pipe is allowed to fall to such an extent that water enters the pipe, the latter shall be removed from the pour and filled with concrete before being again lowered into the placing position.

During and after concreting under water, pumping or de-watering in the immediate vicinity shall be suspended if there is any danger that such work will disturb the freshly placed concrete.

4.6.4 Interruptions to Placing

The face from which placing of concrete is to commence shall be selected so that if an emergency occurs which prevents the layer being completed, the construction joint will be formed in a structurally favorable position.

If concrete placing is interrupted for any reason and the duration of the interruption cannot be forecast or is likely to be prolonged, the Contractor shall immediately take the necessary action to form a construction joint so as to eliminate as far as possible feather edges and sloping top surfaces and shall thoroughly compact the concrete already placed in accordance with Sub-Section 4.7. All work on the concrete shall be completed while it is still plastic and it shall not thereafter be disturbed until it is hard enough to resist damage. Plant and materials to comply with this requirement shall be readily available at all times during concrete placing.

Before concreting is resumed after such an interruption the Contractor shall cut out and remove all damaged or uncompacted concrete, feather edges or any other undesirable features and shall leave a clean sound surface against which the fresh concrete may be placed.

If it becomes possible to resume concrete placing without contravening the Specification and the Engineer consents to a resumption, the new concrete shall be thoroughly worked in and compacted against the existing concrete so as to eliminate any cold joints.

4.6.5 Heights of Concrete Lifts

Concrete in the Permanent Works shall generally be placed in lifts not exceeding 2.5 meters but the Engineer may authorize or instruct different heights to be used according to the section of concrete being placed.

Approval will only be given for placing concrete in lifts exceeding 2.5 m in height where the Contractor demonstrates to the satisfaction of the Engineer that his plant and organization on Site are sufficient to ensure a continuous uninterrupted pour in accordance with the Specification.

4.6.6 Placing Sequence

Unless otherwise approved by the Engineer, concrete shall be cast in one operation between external faces of concrete and joints shown on the Drawings. The sequence of construction shall be such that the effects of shrinkage and thermal contraction are minimized.

The Contractor shall submit a detailed concreting programme to the Engineer for his approval at least one month ahead of concreting.

Where required by the Engineer to limit the opening of construction joints due to shrinkage, concrete shall not be placed against adjacent concrete which is less than 21 days old.

When the Drawings call for contraction gaps in concrete, these shall be of the widths and in the locations shown on the Drawings and they shall not be filled until the full time interval shown on the Drawings has elapsed.

4.7 COMPACTION OF CONCRETE

4.7.1 General Requirements

The Contractor shall thoroughly compact all concrete immediately after it has been placed in position. In general, the concrete shall be placed in layers not exceeding 0.5 meter in depth after compaction. Unless otherwise authorized by the Engineer, compaction shall be accomplished with the aid of approved immersion vibrators, together if necessary with rods, shovels and the like. Particular care shall be taken to fill all voids and to work the concrete against rock and existing concrete surfaces, round any reinforcement and embedded fixtures and into the corners of the formwork.

If the Contractor does not wish to use immersion vibrators for any portion of the Permanent Works, he shall submit his proposals for alternative vibrators or compaction equipment and shall await the Engineer's approval of the equipment before commencing to concrete the portion concerned.

Concrete shall not be subject to disturbance by vibration within 4 hours to 24 hours after compaction.

4.7.2 Vibration Equipment

Vibrators shall be of a type and size capable of fully compacting the concrete being placed.

Vibrators shall operate at a frequency of between 7 000 and 10 000 cycles per minute or to the Engineer's approval.

For concretes containing aggregates of size 75 mm, the vibrators used shall be of at least 100 mm diameter and generally requiring two workmen to operate, but smaller vibrators shall also be available for use in places where access is restricted and adjacent to intricate formwork, waterstops, instruments, pipes, ducts, embedded steelwork, etc.

The number of vibrators in use on each pour shall collectively be capable of achieving the specified compaction at a rate of at least 20% in excess of the average placing rate. In addition standby vibrators of a similar size shall be available for immediate use on each pour. The numbers of such standby vibrators shall be not less than one quarter of the number actually in use as specified above, or a minimum of one where less than four vibrators are actually in use. The pour shall not commence until the specified number of standby vibrators are available at the pour.

Where compressed air vibrators are used the Contractor shall ensure that the air pressure at the pour shall not fall below the operating pressure recommended by the manufacturers of the vibrators and where electrical vibrators are used the Contractor shall likewise ensure that the voltage does not fall below that recommended by the manufacturer for correct operation of equipment.

The length of the vibrating element of immersion vibrators shall be sufficient to penetrate through the layer of concrete being placed and re-vibrate the upper portion of the underlying layer of concrete.

4.7.3 Method of Vibration

Only workmen skilled and experienced in the use of vibrators shall be employed on this type of work.

In compacting large volumes of concrete compaction of the unvibrated heap of concrete shall commence with the vibrators being inserted into the leading face of the heap to form a toe in order to retain the remainder of the heap during compaction. Vibration shall then continue by gradually working towards the previously vibrated concrete. The slope of the face after completion of vibration shall be not steeper than 25° to the horizontal and succeeding buckets shall be discharged partly on top of this face.

Immersion vibrators shall be inserted vertically to penetrate into the layer underneath at regular intervals which shall not exceed the distance from the element over which vibration is visibly effective, and in any case shall not exceed 600 mm. Vibrators shall not be used to move concrete laterally and shall be withdrawn slowly to prevent the formation of voids.

Vibration shall not be applied by way of reinforcement nor shall vibrators be allowed to touch formwork or reinforcement or other embedded items as far as is practicable.

Vibration shall be continued at each point until the concrete ceases to contract, a thin layer of mortar has appeared on the surface and air bubbles have ceased to appear. The period of vibration necessary shall be determined carefully by trial in the presence of the Engineer. Vibration shall be continued for this period at each point before any further concrete is superimposed.

4.8 CURING OF CONCRETE

4.8.1 General

Concrete shall be protected during the first stage of hardening from loss of moisture and from the development of temperature differentials within the concrete sufficient to cause cracking. The methods used for curing shall not cause damage of any kind to the concrete.

Curing shall be continued for as long as may be necessary to achieve the above objectives but in any case for at least fourteen days or until the concrete is covered by later construction whichever is the shorter period.

The above objectives are covered in Sub-Sections 4.8.2. and 4.8.3., but nothing shall prevent both objectives being achieved by a single method where circumstances permit.

The curing process shall commence as soon as the concrete is hard enough to resist damage from the process, and in the case of large areas or continuous pours shall commence on the completed section of the pour before the rest of the pour is finished.

Details of the Contractor's proposals for curing concrete shall be submitted to the Engineer before the placing of concrete commences in the Permanent Works.

4.8.2 Loss of Moisture

The Contractor shall keep the exposed surfaces continuously wet by means of a water spray or by covering with a water absorbent material which is kept wet.

Water used for curing shall be of the same quality as that used for mixing as stated in Sub-Section 4.2.9.

Formed surfaces may be cured by retaining the formwork in place for the required curing period.

If the use of the foregoing methods is inappropriate, surfaces which will not have further concrete bonded to them and which are not to receive an application of a finish may, subject to the approval of the Engineer, be cured by the application of an approved curing compound. Curing compounds shall contain a fugitive dye to enable the extent of the spread to be seen easily.

Curing compound used on surfaces exposed to the sky shall contain sufficient finely divided flake aluminium in suspension to produce a complete coverage of the surface with a metallic finish when applied at the rate recommended by the manufacturer.

Curing compounds shall become stable and impervious to the evaporation of water from the concrete surface within 60 minutes of application. The material shall not react chemically with the concrete and shall not crack, peel or disintegrate within four weeks after application.

If instructed by the Engineer, the Contractor shall, in addition to the curing provisions set out above provide a suitable form of shading to prevent the direct rays of the sun reaching the concrete surfaces for at least the first four days of the curing period.

4.8.3 Limitation of Differential and Peak Temperatures

The Contractor shall limit the development of heat in concrete after placing to such that the temperature gradient at any point within the pour shall not exceed 25°C per linear metre and the absolute temperature at any point shall not exceed 50°C.

In order to achieve this control, the Contractor shall use means appropriate to the circumstances as accepted by the Engineer which may include:

i. limiting concrete temperatures at placing as set out in Sub-Section 4.10.3;
ii. use of low heat cement or p.f.a, subject to the agreement of the Engineer;
iii. insulation of exposed concrete surfaces by insulating blankets. Such blankets shall have a thermal conductivity C value less than 1.0 W/m2/°C;
iv. leaving formwork in place during the curing period (steel forms shall be suitably insulated on the outside);
v. preventing rapid dissipation of heat from surfaces by shielding from wind;
vi. avoiding the use of water sprays when such use would cause rapid cooling of the surfaces and using curing compounds instead;
vii. shielding concrete surfaces from clear night skies, together with the use of heaters where appropriate.

Where instructed by the Engineer, the Contractor shall demonstrate the control of temperature by the installation of appropriate temperature measuring devices at selected locations to monitor the development of temperature profiles.

4.9 PROTECTION OF FRESH CONCRETE

Freshly placed concrete shall be protected from rainfall and from water running over the surface until it is sufficiently hard to resist damage from this cause.

No traffic shall be allowed on any concrete surface until such time as it is hard enough to resist damage by such traffic.

Concrete placed in the Permanent Works shall not be subjected to any structural loading until it has attained at least its required control strength as defined in Sub-Section 4.3.2 (vii).

If the Contractor desires to impose structural loads on newly-placed concrete, he shall make at least three test cubes and cure them in the same conditions as the concrete they represent. These cubes shall be tested singly at suitable intervals in order to estimate the time at which the required compressive strength is reached.

4.10 CONCRETE IN HOT OR COLD WEATHER

4.10.1 General

The Contractor shall prevent damage to concrete arising from exposure to extreme temperatures, and shall maintain in good working order all plant and equipment required for this purpose.

In the event that conditions become such that even with the use of the equipment the requirements cannot be met, concrete placing shall immediately cease until such time as the requirements can again be met.

4.10.2 Concrete Placing in Cold Weather

Provided the ambient air temperature does not fall below 10°C, no special precautions need be taken to protect concrete from the effects of cold weather.

If the ambient air temperature is in the range 0°C to 10°C and freezing conditions are confined to ground frosts during the night, the Contractor shall take precautions as approved by the Engineer so as to ensure that concrete is placed and compacted at a temperature of not less than 5°C and that it is subsequently covered and protected from cold winds and frosts so that its temperature will not fall below 5°C for at least 3 days.

4.10.3 Concrete Placing in Hot Weather

During hot weather the Contractor shall take all measures necessary to limit the temperature of concrete at the time of placing in the Permanent Works and to ensure that the concrete does not lose any moisture during transporting and placing. The concrete temperature at the time of placing shall not exceed 25°C unless the Contractor can demonstrate that a higher

temperature, not exceeding 30°C, allows the subsequent temperature to be controlled as specified in Sub-Section 4.8.3.

Such measures may include but are not necessarily limited to the following:

i. shielding aggregates from direct sunshine;

ii. sun shields on mixing plants and transporting equipment;

iii. Cooling the mixing water – if ice is used for this purpose it shall be in flake form (lump ice shall not be allowed to enter the tank supplying the mixer drum), and no ice shall be present in the concrete when the concrete is discharged from the point of mixing;

iv. covering skips closely with polythene sheet so that the latter is in contact with the concrete;

v. painting all equipment and sun shields white.

Areas in which concrete is to be placed shall be shielded from direct sunshine and rock or concrete surfaces shall be thoroughly wetted if instructed by the Engineer to reduce absorption of water from the concrete placed on or against them. Concrete shall not be placed against formwork that is hotter that 30°C.

After concrete in any part of an area has been placed, the specified curing process shall be commenced as soon as possible. If any interval occurs between completion of placing and start of curing, the concrete shall be closely covered during the interval with polythene sheet to prevent loss of moisture.

4.11 FINISHES ON FREE SURFACES

Horizontal or nearly horizontal surfaces which are not cast against formwork shall be finished to the class shown on the Drawings and defined hereunder.

4.11.1 U1 Finish

All surfaces on which no higher class of finish is called for on the Drawings or instructed by the Engineer shall be given a U1 finish.

The concrete shall be levelled and screeded to produce a uniform plain or ridged surface, surplus concrete being struck off by a straightedge immediately after compaction.

4.11.2 U2 Finish

The surface shall first be treated as a Class U1 finish and after the concrete has hardened sufficiently, it shall be floated by hand or machine sufficient only to produce a uniform surface free from screed marks.

4.11.3 U3 Finish

The surface shall be floated as for a U2 finish but to the tolerance stated below. When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, it shall be teel-trowelled under firm pressure to produce a dense, smooth uniform surface free from trowel marks.

4.11.4 U4 Finish

The requirement is similar to a U3 finish but the permissible tolerances are smaller.

4.11.5 Tolerances

The permissible tolerances on free surfaces shall not exceed the values given in the following table:

Class of Finish	Tolerances in mm (see Note)		
	A	B	C
U1	not applicable	10	+ 15 to - 10
U2	Nil	7	+ 10 to - 7
U3	Nil	5	+ 7 to - 5
U4	Nil	2	+ 5 to - 2

Note: The tolerances A, B and C given in the table are defined as follows:

- "A' is the maximum allowable value of any sudden change of level in the surface;
- "B" is the maximum allowable value of any gradual irregularity of the surface, as indicated by the gap between the surface and a three metre long straightedge or correctly shaped template placed on the surface;
- "C" is the maximum allowable value of the difference in level or position between a straightedge or correctly shaped template placed on the surface and the specified level or position of that surface.

Where dimensional tolerances are given on the Drawings or elsewhere in the Specification they shall take precedence over those given in the table above.

4.12 CONSTRUCTION JOINTS

Whenever concrete is to be bonded to other concrete which has hardened, the surface of contact between the sections shall be deemed a construction joint.

Where construction joints are shown on the Contractor's Working Drawings, the Contractor shall form such joints in those positions. Any change in the location of joints or additional joints which the Contractor requires to make for the purpose of construction shall be subject to the agreement of the Engineer and details shall be submitted with the Programme of Works required by the Conditions of Contract. The exact location of all construction joints shall be submitted to the Engineer at least four weeks prior to the start of construction of the relevant part of the Works. Construction joints shall be in vertical or horizontal planes except

in sloping slabs where they shall be normal to the exposed surface or elsewhere where the Drawings require a different arrangement.

Construction joints shall be so arranged as to reduce to a minimum the effects of shrinkage in the concrete after placing, and shall be placed in the most advantageous positions with regard to stresses in the structures and the desirability of staggering joints.

Feather edges of concrete at joints shall be avoided and any feather edges which may have formed where reinforcing bars project through a joint shall be cut back until sound concrete has been reached.

The intersections of horizontal or near horizontal joints and exposed faces of concrete shall appear as straight lines produced by use of a guide strip fixed to the formwork at the top of the concrete lift, or by other means acceptable to the Engineer.

Construction joints formed as free surfaces shall not exceed a slope of 2% from the horizontal.

Stub columns, stub walls or kickers on footings shall be cast integrally with the base concrete or footing and not afterwards, even when a different class of concrete is to be used in subsequent pours.

The surface of the fresh concrete in horizontal or near horizontal joints shall be thoroughly cleaned and roughened by means of wire brushing after the initial set but prior to the final set, or by means of high pressure water and air jets when the concrete is hard enough to withstand the treatment without the leaching of cement. The surface of vertical or near vertical joints shall be similarly treated if circumstances permit the removal of formwork at a suitable time.

Where concrete has become too hard for the above treatment to be successful, the surface whether formed or free is to be thoroughly scabbled by mechanical means or wet sand blasted and then washed with clean water. The indentations produced by scabbling shall be not less than 10 mm deep and shall not extend closer than 40 mm to a finished face.

Construction joints where curing has ceased and which have dried out shall be kept continuously wet for 48 hours where the surface has dried out for longer than 7 days, and for 24 hours where it has dried out for less than 7 days, before placing the next concrete in addition to being washed shortly before concreting. Shortly before concreting is commenced the surface shall be thoroughly cleaned of all loose concrete, shavings, dust and extraneous material by washing by high pressure water jets, and standing water shall be blown off with clean compressed air. Any standing water in or on the construction joint surface shall be mopped up or blown away by means of compressed air jets. Shutters shall be provided with properly formed windows at the level of the previous pour to permit the proper cleaning of the surfaces before concreting recommences.

If instructed by the Engineer, the surface of the concrete shall be thoroughly brushed with a thin layer of mortar complying with Sub-Section 4.16 and having the same or greater strength as that of the concrete, or microcrete mixed in proportions similar to those of the fines portion

in the concrete to be placed all as set out in Sub-Section 4.6.2, immediately prior to the deposition of fresh concrete. The mortar shall be kept just ahead of the fresh concrete being placed and the fresh layer of concrete shall be thoroughly and systematically vibrated to full depth to ensure complete bond with the adjacent layer.

No mortar or concrete may be placed in position on or against a construction joint until the joint has been inspected and passed by the Engineer.

Construction joints between lifts in mass concrete structures shall incorporate a shear key, generally formed by a 0.25 m high upstand extending the full width of the block between joints, and the central third of the length.

Vertical or inclined construction joints of any kind shall not be permitted in the walls of water retaining structures except where instructed or specifically approved by the Engineer.

The formwork to walls or columns shall be overfilled with concrete when pouring and poorer material such as scum, laitance and porous concrete which collects at the top shall then be removed by striking off level with the top of the formwork within four hours after the concrete is placed.

4.13 EXPANSION AND CONTRACTION JOINTS

4.13.1 General

Expansion and contraction joints are discontinuities in concrete designed to allow for thermal or other movements in the concrete.

Expansion joints are formed with a gap between the concrete faces to permit subsequent expansion of the concrete. Contraction joints are formed to permit initial contraction of the concrete and may include provision for subsequent filling.

Expansion and contraction joints shall be formed in the positions and in accordance with the details shown on the Drawings or elsewhere in the Specification.

4.13.2 Compressible Joint Filler

Compressible joint filler shall consist of sheets or strips of the following materials complying with the requirements of the relevant specifications listed:

i. Bitumen impregnated fibre board and bitumen impregnated cork board – US Federal Specification HH-F-341F or AASHTO Specification M213

ii. Resin impregnated cork board – US Federal Specification HH-F-341E

iii. Flexible foams of expanded polyethylene, polyurethane, PVC or polypropylene – AASHTO Specification M153

iv. Rigid foams of expanded polyethylene polyurethane or polystyrene – BS 4840 or BS 3837.

Other compressible joint filler materials may be used if approved by the Engineer after submission of full specifications and information by the Contractor.

4.13.3 Sealants

Thermoplastic hot-poured sealants shall comply with the requirements of US Federal Specification SS-S-1410B, BS 2499 or AASHTO Specification M173. The sealants shall be of the rubberised bituminous type containing a minimum of 20% natural or synthetic rubber.

Thermoplastic cold-applied sealants shall comply with the requirements of US Federal Specification SS-S-156. The sealant shall be of the rubberised bituminous type containing a minimum of 20% natural or synthetic rubber.

Thermosetting chemically cured sealants shall comply with the requirements of US Federal Specification SS-S-195B, American National Standards Institute Specification ANSI A 116.1 (formerly ASA A 116.1 and USASI A 116.1) or BS 4254. The final IRHD (International Rubber Hardness Degree) of the sealant shall be 20 ± 5.

Other sealants may be used if approved by the Engineer after submission of full specifications and information by the Contractor.

Where the type of sealant is not specified on the Drawings, the selection of the type of sealant to be used in any application shall be generally in accordance with BS 6213 and subject to the approval of the Engineer to ensure that its properties are suitable for the application.

4.14 WATERSTOPS

All references to waterstops include also groutstops.

Waterstops shall be of the material and form shown on the Drawings. No waterstop material shall be brought onto Site until the Contractor has submitted full details of the materials he proposes to use, including samples, and these have been approved by the Engineer. All samples shall be of adequate length for testing.

Waterstops shall be made of materials which are resistant to chlorides, sulphates, or other deleterious substances which may be present in the environment of the Permanent Works.

Rubber waterstops may be of natural or synthetic rubber and shall have an elongation at breaking stress of at least 500 per cent at 25°C and shall be capable of accommodating a transverse movement of at least 50 mm.

Polyvinyl chloride (PVC) waterstops shall be extruded from an unfilled plasticised PVC polymer or copolymer which does not contain any reclaimed or scrap PVC. PVC waterstops shall have an elongation at breaking stress of at least 225% at 25°C and shall be capable of accommodating a transverse movement of at least 10 mm.

Low modulus waterstops shall be of rubber or PVC as described above but shall have an elongation of at least 200% at 25°C under a tensile stress of 6 N/mm2 and shall be capable of accommodating a transverse movement of at least 50 mm.

Hydrophilic rubber waterstops shall be of a compound or combination of materials to impart hydrophilic properties such as 'Hydrotite', 'Adeka Ultra-Seal', 'Earth Shield', 'Supercast SW' or similar approved by the Engineer.

Waterstops shall be supplied in lengths as long as possible consistent with ease of handling and construction requirements.

In rubber or plastic materials joints other than butt joints shall be supplied ready made by the manufacturer. Butt joints shall be made on site in accordance with the manufacturer's instructions and with equipment supplied for the purpose by the manufacturer.

Waterstop material shall be stored carefully on site to avoid damage and contamination with oil, grease, or other pollutants. Rubber and plastic waterstops shall be stored in cool well ventilated places away from direct sunlight.

Hydrophylic waterstops shall be delivered in factory sealed and labelled packaging and protected from moisture that may cause premature waterstop swelling.

Rubber and plastic waterstops which are embedded in one side of a joint more than one month before the scheduled date of placing concrete on the other side, shall be protected from the sun.

Waterstops shall be firmly fixed in the formwork so that they cannot be displaced during concrete placing and shall be completely free of all dirt, grease, oil, etc., before placing concrete. Waterstops shall be placed perpendicular to the plane of the joint and the centre of the waterstop shall correspond with the joint opening.

Concrete shall be placed carefully round waterstops so as to avoid distortion or displacement and shall be fully compacted. Where waterstops lie in a horizontal or nearly horizontal plane the Contractor shall ensure that no voids are left on the underside of the waterstop.

Hydrophylic waterstops shall be installed in accordance with the approved manufacturer's instructions and recommendations.

Formwork around waterstops shall be carefully removed to avoid damage. If waterstops suffer any damage which cannot be properly repaired in situ the Engineer may require a section of concrete to be removed and the waterstop replaced.

Vertical waterstops commencing at rock level shall be anchored into pockets cut into the foundation. The pockets shall be 400 mm x 700 mm x 500 mm deep, and the sides shall not slope more than 20° from the vertical. The preferred method of forming the pockets shall be by line drilling or core drilling, where this is possible. The pockets shall be thoroughly washed and cleaned, and backfilled from the bottom upwards with concrete of the same strength as the parent concrete but in all cases with 20 mm aggregate.

4.15 RECORDS OF CONCRETE PLACING

Records in a form agreed by the Engineer shall be kept by the Contractor of the details of every pour of concrete placed in the Permanent Works. These records shall include class of

concrete, location of pour, date of pour, ambient temperature and concrete temperature at time of placing, moisture contents of aggregates, details of mixes, batch numbers, cement batch number, results of all tests undertaken, location of test cube sample points and details of any cores taken.

The Contractor shall supply to the Engineer four copies of these records each week covering work carried out during the preceding week. In addition he shall supply to the Engineer monthly histograms of all 28 day cube strengths together with accumulative and monthly standard deviations and any other information which the Engineer may require concerning the concrete placed in the Permanent Works.

4.16 MORTAR

This clause covers mortar for use ahead of concrete placing, and other uses not covered elsewhere in the Specification.

Mortar shall be composed of fine aggregate complying with Sub-Section 4.2.4 and the type of cement specified. The mix proportions shall be as stated on the Drawings or elsewhere in this Specification or if not stated shall be one part of cement to two parts of fine aggregate by weight.

Small quantities of mortar may be hand mixed but for amounts over 0.5 m^3 a mechanical mixer shall be used.

The water content of the mortar shall be as low as possible consistent with the use for which it is required but in any case the water:cement ratio shall not be more than 0.5.

Mortar which is specified as 'dry pack' shall be mixed with sufficient water for the mix to become cohesive but not plastic when squeezed in the hand. Dry pack mortar shall be rammed into the cavity it is required to fill, using a hand rammer with sufficient force to ensure full compaction.

4.17 CONCRETE FOR NON STRUCTURAL PURPOSES

Non-structural concrete (NS concrete) shall be used only for non-structural purposes where shown on the Drawings or agreed or directed by the Engineer.

NS concrete shall be composed of aggregates complying with all-in aggregate within the grading limits of Table 5 of BS 882, Sub-Section 4.2.4 and the type of cement specified.

The weight of cement mixed with 0.3 m3 of combined or all-in aggregate shall not be less than 50 kg. The mix shall be proportioned by weight or by volume. The maximum aggregate size shall be 40 mm nominal.

The concrete shall be mixed by machine or by hand to a uniform color and consistency before placing. The quantity of water used shall not exceed that required to produce a concrete with sufficient workability to be placed and compacted where required.

The concrete shall be compacted by hand or by mechanical vibration.

No Fines concrete (NF concrete) is intended for use where a porous concrete is required and shall only be used where shown on the Drawings or instructed by the Engineer.

The mix shall consist of the cement specified and aggregate complying with this section. The aggregate size shall be 40 mm to 12 mm only or as shown on the Drawings or directed by the Engineer. The weight of cement mixed with 0.3 cubic meter of aggregate shall not be less than 50 kg. The quantity of water shall not exceed that required to produce a smooth cement paste which will coat evenly the whole of the aggregate.

Blinding concrete shall be Class 15/40 or Class 20/20 as indicated on the Drawings.

4.18 SHOTCRETE (SPRAYED CONCRETE)

4.18.1 Scope of Work

This clause applies to shotcrete required in any part of the Works including underground works and includes sprayed mortar.

The work under this Section includes all labour, materials, equipment and services required for the execution of shotcrete work under this Contract. Shotcrete shall be applied to unstable or weak rock surfaces along the tunnel according to the temporary support classes shown on the drawings or as directed by the Engineer.

The Contractor shall design the mix, furnish materials, place, cure and test shotcrete as necessary to provide temporary or permanent protection and/or support of excavation surfaces.

The Contractor shall furnish all materials, labour and equipment for preparing test panels, both for trial mixes and during the course of the work, and for testing cores from panels or from in-situ shotcrete.

When the shotcrete is intended to remain as a permanent protection of rock/soil surfaces, the thickness of such lining shall be as specified in the drawings or as directed by the Engineer.

Shotcrete shall be placed with meshes of welded wire fabric, as specified, and may be used in conjunction with rock bolts.

Where applicable, and subject to approval by the Engineer, shotcrete reinforced with welded wire fabric meshes may be replaced by steel fibre shotcrete mix by means of equipment designed for that purpose.

The Contractor shall maintain adequate stockpiles of materials for shotcrete for immediate use. Any damage or delay resulting from shortage of such materials shall be to the Contractor's expense.

4.18.2 Submittals

At 30 days from the date of receipt of Notice to Commence, the following submittals shall be sent to the Engineer for approval:

- details, including numbers and type of equipment proposed for mixing, applying and curing the shotcrete;
- manufacturers' certificates giving full details of any proposed admixture, and the Contractor's proposal regarding the use of such admixtures, including certification of harmlessness to operatives;

The selection of method, i.e. dry-mix or wet-mix process is the Contractor's option.

4.18.3 Standards

The aspects of shotcrete construction including equipment, crew organisation, preliminary preparation, proportioning, shotcrete placement, and quality control shall conform to the requirements of ACI Manual of Concrete Practice, Part 5, Guide to Shotcrete, reported by the ACI Committee 506 or any other approved guideline or as directed by the Engineer.

4.18.4 Materials

Cement, aggregate, water, and admixtures shall comply with Sub-Section 4.2, except as noted below.

a. Aggregate

Aggregate gradation used in shotcrete shall conform to those established by the pre-construction trial mix tests. The gradation shall not be changed without the prior approval of the Engineer. Unless otherwise approved by the Engineer, the percentages of fine and coarse aggregate shall conform to the gradings, measured by weight, shown in the following table. They shall be taken as a guide for mix design purposes, but may be modified, subject to the results of the trial mix tests specified hereinafter.

Shotcrete or mortar made with finer sand will have a higher water requirement and correspondingly increased drying shrinkage.

The following table gives the recommended aggregate grading envelopes for shotcrete.

Sieve Size		Fine Aggregate	Coarse Aggregate	
US Standard Sieve	mm		2.5 – 10 mm	5 – 18 mm
1”	25	–	–	100
¾”	18	–	–	90 – 100
½”	12	–	100	–
3/8”	10	100	85 – 100	20 – 55
No. 4	5	95 – 100	10 – 30	0 – 10
No. 8	2.5	80 – 100	0 – 10	0 – 5
No. 16	1.25	50 – 85	0 – 5	–

No. 30	0.63	25 – 60	–	–
No. 50	0.315	10 – 50	–	–
No. 100	0.160	2 – 10	–	–

The maximum aggregate size fractions of the mix shall depend on the shotcrete thickness and be determined by suitability tests.

No more than 5% of the aggregate, by weight, shall pass the US Standard Sieve No.200 (0.075 mm). In the case of manufactured sand, if the material finer than the No. 200 sieve (0.075 mm) consists of the dust of fracture, essentially free of clay or shale, these limits may be increased to 7%.

Should the nature of the aggregates used during the course of the work change (e.g. source, rock type, shape) from that used in the trial mix tests, the Contractor shall produce new trial mixes, using the new aggregates.

b. Water

Mixing water shall be clean and free from substances which may be injurious to concrete or steel.

c. Admixtures

Admixtures may be used in shotcrete to enhance certain shotcrete properties, for special shotcrete applications, and for certain conditions of shotcrete placement.

Admixtures shall meet the requirements of the Sub-Section 4.10 of this Specification.

The use of admixtures in shotcrete shall be tested prior to large scale use to determine that the advantages expected are obtained.

The use of some rapid set accelerators results in considerable reductions of ultimate shotcrete strength, and they shall be thoroughly evaluated before use. Some of these admixtures are caustic and care shall be exercised in handling them. Only accelerating agents free from chloride shall be used.

d. Reinforcement

Welded wire fabric (mesh) shall conform to the relevant Standard BS 4483 of this Specification. General requirements are described in the Sub-Section 3 of this Specification.

As an alternative to welded wire fabric meshes, the Contractor may propose the use of fibrous reinforcement (steel fibres), containing artificial fibres of size and concentration recommended by the manufacturer for the intended use, or as otherwise approved by the Engineer.

Recommendations of ACI Committee 544 "State of the Art Report on Fiber Reinforced Concrete (ACI-544.I.R.-82) shall be applied for the use of steel fibre reinforced concrete.

4.18.5 Batching and Mixing

The correct proportions of sand and cement shall be established by weigh batching and cement shall not be added more than 1 hour before the time of placing the shotcrete.

The sand shall be dampened or dried as required to bring the moisture content to a satisfactory consistent level. Fluctuations in moisture contents shall be minimised.

The water:cement ratio of the fresh shotcrete in place shall be in general between 0.35 and 0.50. The mix will contain sufficient water to meet the required water/cement ratio but less water than will cause sloughing.

The mixing equipment shall be capable of thoroughly mixing the aggregate and cement so that the aggregate particles are thoroughly coated and capable of producing the mix in sufficient quantity to maintain continuity of placing. The Contractor shall demonstrate that the mixing plant he proposes to use is capable of meeting these requirements.

The mixer shall be self cleaning and capable of discharging all material without any carrying-over from one batch to the next. It shall be inspected by the Contractor and thoroughly cleaned at least once a day.

The quantity of any additive used shall be kept to the absolute necessary minimum and shall be fed by the machine direct and in the exact proportion by weight.

The non-lift mixing process shall take at least two minutes and the composition of the mix shall remain unchanged until it is applied.

During handling, the mixed concrete shall be protected against dripping water.

The use of ready mix from transit-mixing plants is allowed for subordinate structural parts only and is subject to explicit approval by the Engineer in writing.

4.18.6 Procedures

Before commencing application of shotcrete, the Contractor shall submit to the Engineer full details of the plant he proposes to use for the mixing and application of shotcrete and of the arrangements he proposes to make.

Prior to start of spraying concrete operations in any area the Contractor shall, in close cooperation with the Engineer and as part of the initial application establish procedures for the application of shotcrete which will produce the best quality product with the minimum of rebound. Such establishment of procedures shall include minor variations to mixes, if required, and the establishment of acceptable finishes and thicknesses of layer and quantities to be discharged at the nozzle to a unit area of rock or other surfaces, as required by the Engineer.

The Contractor shall develop operating procedures and operations to the satisfaction of the Engineer to give:

- minimum rebound
- no inclusion of rebound in the finished shotcrete

- as smooth a finished surface as possible
- no hollow area in the shotcrete
- a minimum of shrinkage cracks, and
- good adherence of the shotcrete to rock or other surface.

The Contractor shall make available all and any equipment, machinery, etc., meeting the requirements of continuous spraying procedure, particularly with respect to the workmanlike construction of the thick shotcrete linings, if any, with a structural function.

The Contractor shall advise the Engineer of the brand names and type, number and capacity of the spraying machines he proposes to use, together with all other equipment required to carry out the spraying operations. All equipment shall require approval by the Engineer. The spraying method shall be indicated.

All equipment required to prepare, mix and place shotcrete shall be kept clean and maintained in good operating conditions at all times during the performance of the works.

The shotcrete machine shall have an adequate placing capacity to ensure minimum delays to excavation and other operations. The equipment shall be such that the rapid hardening additive can be mixed satisfactorily and immediately before placing.

The air supply shall have sufficient capacity to meet the requirement for the size of nozzle and the working conditions. The water supply shall be pressurised to overcome the air pressure at the nozzle to ensure that the water is intimately mixed with the other materials.

The Contractor shall ensure that the air compressor he intends to employ is of sufficient capacity to maintain continuity of placing. The compressor shall maintain a supply of clean dry air adequate to maintain sufficient nozzle velocity for all parts of the work while simultaneously operating a blow pipe for clearing any rebound if required.

The quality of the shotcrete as placed depends on the experience and reliability of the operators as well as on the correct nozzle spacing and spray angle. Only trained and tested operators with appropriate experience shall be employed for shotcrete operations. The Contractor shall satisfy the Engineer that the personnel are capable of doing work of a high standard prior to any shotcrete work being undertaken in the Works. For this purpose each nozzleman and back-up team shall carry out a series of trial applications in the presence of the Engineer to demonstrate their ability in applying shotcrete on vertical and overhead surfaces. Test panels as described in Sub-Section 4.18.5 shall be made by each operator. No operator will be approved unless the 28 day crushing strength of all tests exceed the design requirements.

If, in the opinion of the Engineer, operation of spraying equipment becomes unsatisfactory, the Contractor shall make all necessary repairs or replacement of the equipment. The Engineer may direct that spraying ceases until the Engineer's instructions are complied with, and the Contractor shall have no grounds for any additional payments or extension of time on this account.

In all areas where excavation is proceeding, the Contractor shall ensure that sufficient equipment is available to apply shotcrete at any face.

4.18.7 Mix Design

The mix design shall be carried out by the Contractor and details submitted to the Engineer for approval. The proportions shall be developed in accordance with the recommendation of ACI 211.1 and ACI 214 for obtaining specified compressive strengths. Aggregate content corrections shall be done in the case of wet-mix process. Shotcrete mixes shall not be used in the Works until approved by the Engineer. Mix proportions shall be varied as directed to maintain rebound at a minimum.

Mixes shall be such that the aggregate gradation and cement content after placing are as those obtained from samples taken from test panels produced from approved trial mixes. All constituents shall be uniformly dispersed throughout the mix. The use of admixtures in shotcrete shall be tested for compatibility with cement in accordance with ASTM C 1141 prior to large scale use and to determine that the advantages expected are obtained.

Accelerator (e.g. Sigunit of SIKA or approved equal) shall be added to the mix to speed-up the setting rate of the cement. The maximum content of accelerator by weight of cement shall be according to manufacturer's instructions.

4.18.8 Preconstruction Testing

For the purpose of approving mix design, the Contractor shall prepare not less than four test panels for each mix for testing in the presence of the Engineer initially at 30 days before any shotcrete placing is started in the Works, before approval of an additive is given, when the use of new equipment is proposed, and subsequently whenever, in the opinion of the Engineer, shotcrete is being produced which may not meet this Specification.

Preparation and testing shall comply with ASTM C 1140. The Contractor shall furnish all plant, equipment, materials and assistance necessary and carry out all work to obtain representative test panels of shotcrete.

Test panels moulds at least 750 mm square and at least 150 mm thick shall be constructed for each mix designed and for each position required in the works such as downhand, vertical and overhead positions, and for each proposed nozzleman. Panel moulds shall be formed from plywood at least 20 mm thick, be adequately braced and be held rigidly in position. Panels shall be made in the presence of the Engineer.

Separate test panels shall be constructed with and without accelerator. For each important shotcrete section of the Works one test, consisting of three panels, shall be performed.

The test panels shall be positioned alongside the area of placement and at the same angle and shall be sprayed by each proposed nozzleman in rotation so that the tests shall represent the quality of the shotcrete being placed by each nozzleman.

The panels shall be left undisturbed at the point of placing until the final set has taken place. They shall be kept moist and at 21°C ± 5°C until moved to test laboratory.

Test panels and specimens shall be transported by the Contractor to the Site Laboratory immediately after final set has taken place and in such a manner as to prevent their being damaged in any way.

Five drilled cores with a diameter of 100 mm and L/D of at least 1 (L: Length, D: Diameter) shall be obtained from each panel at right angles to the plane of the panel. Cores shall not be taken within 10 cm of the edges of the panel.

Visually grade the reinforced specimens for compliance with grade requirements of ACI 506.2. Determination of grade shall be by computing the mean of a minimum of three test specimens, by excluding the best and worst test result of the five tested specimen. A mean grade of 2.5 or less is acceptable. Individual shotcrete cores with a grade greater than 3 are unacceptable.

Only nozzlemen with a test panel mean core grade less than or equal to 2.5 shall be allowed to place job shotcrete. When the prequalification test panel is rejected, a second panel may be shot. When the nozzleman's second mean core grade is greater than 2.5, the nozzleman shall not be permitted to shoot on the project.

The non-reinforced specimens shall be tested for compliance with the specified physical properties in accordance with ASTM C 42.

After 12 hours five cores from one test panel shall be tested for compression and the average is calculated by deleting the best and worst test result. In the case cores can not be drilled after 12 hours, non-destructive strength tests (impact hammer), as specified further, shall be carried out by the Contractor in the presence of the Engineer.

Five specimens from another test panel shall be core drilled and tested for compression and the average is calculated by deleting the best and worst test result at 24 hours. After 48 hours five specimens from the last test panel shall be core drilled and carefully stored. At 28 days these specimens shall then be tested for compression and the average is calculated by deleting the best and worst test result. The core testing shall be carried out in the Contractor's laboratory.

Core strengths shall be corrected for L/D as described in ASTM C 42. The cores shall be stored, cured and tested in accordance with ASTM Standard Method C 42. All cores shall be suitably labelled to identify them with the panels from which they have been taken, and the location in the Works to which they relate.

The required cylinder compressive strength for each set of five 12-hours cores, by deleting the best and worst test result (5 N/mm²), 24-hours cores (10 N/mm²) as well as 28-day cores (25 N/mm²) shall be satisfied if the mean compressive strength of a test set of three cores (by testing five cores and deleting the best and worst result) shall equal or exceed 1/0,85 (= 118%) of the specified cylinder compressive strength with no individual core with a compressive strength less than the required cylinder compressive strength.

Should any of the cores reveal defects such as a lack of compaction, dry patches, voids or sand pockets, or should the strength test results be unsatisfactory, the Engineer may require

further tests or cores to be taken from the remainder of the panel(s) or he may reject the procedure used to make the defective test panel and require that a replacement test panel be made with a modified procedure.

The procedures described above shall determine the optimum proportions to achieve the result desired. Once the mix proportions have been established they shall be monitored.

4.18.9 Work Quality Control

One test panel shall be sprayed for every 100 m³ of shotcrete applied, measured in theoretical quantities. Fifteen cores of 100 mm diameter shall be drilled from the panel. Five cores each shall be tested for compressive strength after 1, 7 and 28 days.

Test panels for shotcrete quality control to determine the suitability of admixtures shall be made as specified previously for preconstruction testing and as directed.

The required cylinder compressive strength for each test set of three 12-hours cores (5 N/mm²), 24-hours cores (10 N/mm²) as well as three 28-day cores (25 N/mm²) shall be satisfied if the mean compressive strength of a set of three cores (by testing five cores and deleting the best and worst result) shall equal or exceed 1/0,9 (= 111%) of the specified cylinder compressive strength with no individual core with a compressive strength less than the required cylinder compressive strength.

In the case cores cannot be drilled after 12 hours, non-destructive strength tests (impact hammer), shall be carried out by the Contractor in the presence of the Engineer in order to determine the early compressive strength of shotcrete. The Engineer may also require non-destructive strength tests before 12 hours after shotcrete placement.

Non-destructive strength tests will be carried out by means of dynamic ball impact hammers which shall be supplied by the Contractor, including equipment calibration. Impact hammers shall be suitable also for early strength determination, i.e. approximately 10 N/mm² or lower. Testing shall be performed and evaluated in compliance with DIN 2048 or equivalent international standard.

The Contractor shall drill cored holes not less than 25 mm in diameter in places instructed by the Engineer to determine the thickness of shotcrete. Alternatively the Contractor, subject to the agreement of the Engineer, may fix thickness indicators at not more than one metre centres on the surface to which the shotcrete is to be applied. Such indicators shall be easily visible during and after the spraying operation.

When instructed by the Engineer, the Contractor shall drill 100 mm diameter cores in the shotcrete, and these cores shall be tested in a similar manner to those from the test panels.

Test holes in shotcrete surfaces shall be filled by ramming in dry pack concrete of a similar mix to the surrounding concrete which shall be finished flush.

4.18.10 Control of Rebound

Under no circumstances shall rebound be worked back into the construction. If it does not fall clear of the work it must be removed. Rebound which has been removed shall not be

included in later batches. The quantity and nature of rebound shall be ascertained at the request of the Engineer.

All rebound must be removed from the working area and Site by skip, chute or similar method. The rebound shall not cause any contamination of adjacent structures or completed work.

The basic screening necessary to avoid contamination from the shotcrete process and the means of disposal of the rebound material from the working area shall be provided by the Contractor. The Contractor shall satisfy the Engineer that the measures provided are adequate to provide complete compliance with this clause.

4.18.11 Application

Shotcrete can be applied by two methods, either the dry mix method or the wet mix method, the choice of which shall be at the discretion of the Contractor.

a. Dry Mix Method

Applying this method, materials are pre-mixed and then fed to the gun. At the same time an accelerator is added to the gun. The material is then carried in suspension by compressed air through a hose to the nozzle. At the nozzle, water is injected into the material in a number of fine streams. As the material passes through the final portion of the nozzle, it is mixed with the water. Mixing continues as the stream of material and water passes between the nozzle and the point of impingement.

b. Wet Mix Method

Applying this method, materials are pre-mixed with water added in the required ratio and then fed to the pumps. Concrete accelerators will be injected in the pressurised air line at the nozzle of the shotcreting hose and then sprayed onto the surface to be sprayed with concrete.

c. General

Shotcrete shall be applied so that it neither sags nor slumps, and each layer shall be not less than 50 mm thick unless otherwise shown on the Drawings.

Formwork or guides shall be fixed rigidly. Reinforcement shall also be fixed rigidly so that no movement occurs during spraying. If shotcrete is applied directly onto the rock, the reinforcing wire mesh has to be fixed to the rock as tightly as possible, in order to reduce the movement of the reinforcement to a minimum.

During starting or stopping the spraying operation, or when the delivery from the nozzle is irregular, the nozzle shall be directed away from the work.

The flow of the material at the nozzle shall be continuous and uniform and the rate of application over any given area shall be uniform. Slugs, sand spots, wet areas or other defects shall be cut out and corrected as specified herein.

When shotcreting is to be performed near existing structures, the Contractor shall ensure that no damage results to the structure and shall protect the surfaces of structures before shotcreting.

The quantities of shotcrete to be discharged at the nozzle shall be determined on the basis of the average thickness of shotcrete shown on the drawings or required by the Engineer and taking due account of rebound. Once procedures for the application of shotcrete are established, subsequent work shall be carried out accordingly.

If reinforcement is to be embedded, shotcrete shall be applied so that voids cannot form under the steel bars.

The water pressure shall be greater than the air pressure in case of the dry shotcreting method to ensure complete wetting of the materials at the nozzle and to give the nozzleman a quick, positive control.

Compressed air and pressure water shall be free from oil and shall not be liable to pressure fluctuations.

In the case of applying the wet shotcreting method the air pressure recommended by the manufacturer's instruction shall be maintained. Shotcrete shall be applied to rock surfaces as soon as possible after excavation and removal of spoil. For inclined surfaces application shall begin at the bottom.

Before a succeeding layer of shotcrete is placed, the preceding layer shall be checked for drumminess, to the satisfaction of the Engineer. The Contractor shall repair all drummy, sandy, cracked or spalled areas and any other areas where, in the opinion of the Engineer, the shotcrete is faulty, by removing the shotcrete to a sound area of rock or shotcrete, carrying out surface preparation as specified herein and reshooting that area to the satisfaction of the Engineer.

The working area shall be well illuminated to a minimum lighting intensity of 50 lux. Caplamps attached to safety helmets shall not be accepted as sufficient. Dust pollution shall be minimised by means of pre-damping of materials, additional ventilation, water sprays, and maintaining equipment in good order. Protective clothing and dust masks shall be provided for and used by operators.

If at any time the Engineer considers that the environmental conditions of the area where shotcrete is being applied are likely to cause a health hazard or affect the quality of the finished work because of excessive dust or lack of adequate ventilation or lighting, he may order the Contractor to suspend operations on shotcrete work until steps are taken to improve the conditions in the affected area. No additional payment will be made either for the additional measures called for or for any delays resulting from such suspension of works.

Concrete shall not be sprayed when the air temperature is 5°C or less.

Freshly sprayed shotcrete shall be completely protected from drying out for a minimum period of three days after spraying.

4.18.12 Filling of Soft Indented or Shattered Areas

Where instructed by the Engineer, the Contractor shall fill soft indented or shattered areas of the rock face with shotcrete. The preceding layer shall be allowed to harden before the following layer is applied.

4.18.13 Tolerances on Finished Surfaces

In the case of tunnels the finished surface shall not project beyond the clearance surface indicated on the Drawings.

All surface finishes are to be reasonably uniform in texture and free from blemishes. If any surface shows a lack of compaction or bond, dry patches, voids, sand pockets, sags or slumps, the material shall be removed immediately over an area not less than 300 mm square and resprayed at once.

Finished shotcrete surfaces shall be such as to require no further treatment. If surface finish and roughness do not satisfy the Engineer, or do not meet the requirements of a minimum radius of 300 mm for edges in the shotcrete lining or of a depth/height less than 1/10 of the span of any depression/protrusion, then a thin levelling course shall be placed on the fresh shotcrete on the instructions of the Engineer. This thin levelling course shall be included in the unit prices for the respective shotcrete items. Whether or not a smooth finished surface is additionally required will be decided by the Engineer.

4.18.14 Water Pressure Relief Holes

Water Pressure relief holes shall be drilled through permanent shotcrete surfaces where shown on the Drawings or if directed by the Engineer. The holes shall be a minimum of 38 mm diameter and be drilled at least 100 mm into rock.

When drain holes have been drilled and instruments have been installed into rock on which shotcrete is to be placed, the Contractor shall take all necessary precautions to prevent such holes from being plugged or instruments from being damaged.

4.18.15 Shotcrete Applications – General

Shotcrete whether as a sealing tunnel lining or as an arch with load bearing functions shall show in the entire cross-section a uniform, compact, monolithic (not stratified) texture, free of cracks. Any openings in the rock formation shall be secured against loosening and undue yielding of the rock by the shotcrete layer.

All steel parts such as wire, reinforcing steel, mesh, rock bolts, rock bolt plates and nuts, arched steel rib supports (lattice girders) and the like remaining in the shotcrete shall be covered neatly throughout their entire extent by at least 30 mm of shotcrete.

Any adherent rebound and/or loose or clogged material from previous applications shall carefully be removed before spraying. Any steel inserts shall be fixed in such a way that they will not give rise to laminated cross-sectional separation.

If local conditions permit and economy of work is not prejudiced, the sprayed-on concrete layer as a final tunnel lining may assume any structural functions required.

The Contractor shall be fully responsible for an efficient method and the use of appropriate equipment. This responsibility shall rest with him also in cases where subcontractors may be engaged for this work.

4.18.16 Shotcrete Application Above Ground

Spraying concrete above ground shall not be carried out when, in the opinion of the Engineer shotcrete cannot be placed effectively because of adverse weather and wind conditions, unless adequate cover is provided over the working area until the shotcrete has been cured sufficiently to prevent damage.

4.18.17 Curing

During a period depending on local conditions and to be agreed upon with the Engineer, the freshly placed shotcrete shall be protected against sunshine, cold, rain, running water, chemical attack, and vibrations until it hardens, and it shall be kept moist for at least 7 days. If shotcreting is carried out under adverse weather conditions or low temperatures, an additional protective application shall be provided.

In case of open air spraying, the surface shall be protected from the direct rays of the sun for the first 3 days.

4.19 CONCRETING AROUND PIPES

Where pipes pass through or are to be set into concrete work, they shall be well cleaned (to bare metal in the case of ductile iron or steel pipes) and the concrete worked thoroughly into contact with the pipe wall.

The Contractor shall take particular care to ensure that pipes are correctly aligned and that shuttering is carefully cut to the shape of the pipe. No concrete shall be poured until these preparations have been completed to the satisfaction of the Engineer.

Pipes should in all cases preferably be cast into concrete. Openings may be left into which pipes are to be set at a later stage only with the specific approval of the Engineer. If the Engineer approves an opening for this purpose, a square hole to accommodate the pipe shall be left in the concrete exposing part of the reinforcement, and a recessed central key formed in the bottom and sides of the opening. The key shall be not less than 50 mm deep and tapering from 75 mm wide at the surface to 50 mm wide at its base. The dimensions of the hole shall be the minimum necessary to accommodate the largest cross section of the pipe and permit filling of the hole with concrete in accordance with this Specification.

Prior to filling with concrete the surfaces of the existing surrounding concrete shall be roughened, moistened and coated with an approved Epoxy adhesive to aid adhesion and ensure a sound bond. The pipe shall be then set into position and the hole filled with concrete. Formwork shall be so arranged that concrete can be poured into the opening from

one side and rise up the other side to a level at least 300 mm above the top of the opening. Excess concrete shall then be removed while still green, and all surfaces neatly finished and thereafter kept moist until set by wrapping with wet sacking or some other approved method. Once set the joint between the new and the old concrete shall be hacked back on both sides of the wall to form a V-joint 20 mm deep and caulked with cement caulking with an approved epoxy mortar admixture.

4.20 GROUTING OF POCKETS AND HOLES, UNDERPINNING OF BASEPLATES, SETTING FRAMES

Pockets and holding-down bolt holes shall be thoroughly cleaned out using compressed air and water jets. Holes drilled by a diamond bit shall be roughened. The pockets and holes shall be filled either with a proprietary non-shrink chloride free grout approved by the Engineer or with grout consisting of cement and clean fresh water mixed in the proportion of two parts by weight of cement to one part by weight of water. The pouring of liquid grout shall cease as soon as each hole is filled, and any excess grout on the surface of the concrete foundation shall be completely removed and the surface dried off before the next operation proceeds.

Where recesses to be filled are of significant dimensions the Engineer may instruct the Contractor to use a mix of one part cement to two parts sand and small stone aggregate to reduce shrinkage.

The space between the top surface of foundation concrete and the underside of baseplates shall be filled either with a proprietary non-shrink chloride free grout approved by the Engineer or with a special mortar made up in the following proportions:

- Portland Cement 50 kg
- Fine aggregate 50 kg
- Additive an additive acceptable to the Engineer to counteract shrinkage in proportions recommended by the manufacturer.

The special mortar shall be mixed with the lowest water/cement ratio which will result in a consistency of mix of sufficient workability to enable maximum compaction to be achieved.

The special mortar shall then be well rammed in horizontally below the baseplate and from one edge only until it is extruded from the other three sides. The mortar which has extruded shall then be rammed back to ensure complete support without voids.

Proprietary grouts shall be used in accordance with manufacturer's instructions. The Contractor shall obtain the approval of the Engineer to use such proprietary grouts not less than four weeks prior to their intended use in the Permanent Works.

Where necessary bolts shall be set directly into position by template. A small annular opening may be provided when holding-down bolts are set into concrete to provide for final adjustment by bending. Manhole frames, step irons and all such metal work are wherever possible to be set directly in place, or else where necessary bedded on a previously prepared bed of concrete or mortar, and the surrounding concrete carefully tamped into

contact with the metal work. After the concrete has set and the formwork has been removed, the surface of the concrete shall be neatly finished off by pointing around metal work, and all exposed metal surfaces shall be carefully cleaned and a double coat of black bituminous paint applied unless otherwise indicated on the Drawings or in the Bill of Quantities.

Bolt holes shall be formed in concrete either by setting tapered boxes into position before concrete is placed, or by drilling into the concrete after it has set. The method to be adopted shall be at the discretion of the Engineer.

The position of bolt holes shall be to a maximum tolerance of ± 10 mm, and the Contractor shall be responsible for ensuring that the position and alignment of each hole is such as to provide a satisfactory bolted connection. Care must be taken to ensure that the depth of any hole is not excessive.

4.21 HAND MIXED CONCRETE

Concrete for structural purposes shall not be mixed by hand. Where non-structural concrete is required, hand mixing may be carried out subject to the agreement of the Engineer.

The mixing shall be done on a hard impermeable surface. The materials shall be turned over not less than three times dry, water shall then be sprayed on and the materials again turned over not less than three times in a wet condition and worked together until a mixture of uniform consistency is obtained.

For hand mixed concrete not more than 0.5 m3 shall be mixed at one time. During windy weather efficient precautions shall be taken to prevent cement from being blown away during the process of gauging and mixing.

4.22 CONCRETE LININGS IN UNDERGROUND WORKS

4.22.1 Method of Working

The Contractor shall submit to the Engineer full details of the Constructional Plant he proposes to use, the methods of work he proposes to adopt and the programme he proposes to follow in placing concrete linings in underground works. The details to be submitted shall include a statement of the procedure to be followed to ensure that the excavated profile gives the required minimum lining thickness.

The installation of the concrete lining inside the tunnels and shafts is allowed as soon as the trend lines of deformation monitoring suggest that the deformations at any part of the tunnel cross section are and will stay within a limit of maximum 1.00 mm per month.

4.22.2 Lining Formwork

Formwork for tunnel linings shall be approved by the Engineer. It shall be rigid and strong and capable of being adjusted accurately to the prescribed alignment.

The formwork shall generally be faced with metal or other approved material for repetitive sections of the work and shall be provided with openings having an area of not less than 0.5

m² at three metre centres horizontally and circumferentially. A series of openings shall be provided in the crown of the formwork. All openings shall be provided with rigid closing pieces secured by a system of positive quick action locks. The closing pieces shall be constructed to close tolerances and shall be maintained to a standard that will ensure on completion a surface free from irregularities and loss of grout.

The formwork shall be grout tight and the Contractor shall pay particular attention to the use of seals built into the shutter to ensure a grout tight joint between the walls and invert of the tunnel and at the construction joints.

Formwork to transitions and other non repetitive sections may be constructed with timber built up of splines, but in accordance with the foregoing requirements for access hatches and grout tightness. The formwork shall be lined with plywood or other suitable materials so that board markings are eliminated.

4.22.3 Concrete for Linings

Concrete shall be of the class shown on the Drawings. It shall comply with the relevant clauses of this Section of the Specification and have a workability suitable for placing in accordance with Sub-Section 4.22.5.

4.22.4 Preparation of Surfaces

The ground against which concrete is to be placed shall be cleaned to remove all loose material, dirt and debris. Water lying on surfaces shall be removed and water entering the area to be concreted shall be diverted so that it cannot damage the placed concrete. Rock bolts, anchor bars and other fastenings and previously applied shotcrete shall be in a condition satisfactory to the Engineer.

4.22.5 Placing Concrete in Linings

Concrete shall be placed so that the space between the formwork and the surrounding ground is completely filled including any voids over the arch of tunnels and other similar places and so that no voids, honeycombing or cold joints are visible on the face of the lining after completion.

Notwithstanding any agreement of the Engineer to the concreting cycle proposed by the Contractor, the period of such cycle shall be extended in the event of damage being caused to the concrete lining due to too early removal of the formwork.

The Contractor shall take such precautions and adopt such methods as will ensure that all voids in the excavations are completely filled with concrete and that the space between the shutter and the rock is completely filled and free from honeycombing particularly at the crown of the arch.

The concrete shall be transported from the mixing plant in suitable vehicles which shall ensure that there is no segregation of materials during transportation. The rate of supply shall be carefully matched to ensure that cold joints do not form in the concrete and that all concrete is placed in its final position within 45 minutes of being mixed.

Concrete for hydraulic tunnel linings shall be pumped into position by a positive displacement reciprocating pump located close to the section being lined and using methods which do not cause segregation or require remixing of the concrete. Pneumatic placers shall not be used. The location of pipework associated with pumping shall be approved by the Engineer.

Concrete in the walls of tunnels shall be placed through the openings in the formwork and compacted with immersion vibrators. The placing shall continue equally in parallel layers in both wall until only the crown of the arch remains to be completed.

Placing of the concrete in the arch shall be either by pumping from the end adjacent to the construction joint and forcing the concrete towards the stopend shutter or by immersing the open end of the supply pipe in the concrete and gradually withdrawing the supply as the concrete advances. The point of discharge when concreting the crown above the springline shall be kept buried sufficiently to allow enough pressure to be built up to completely fill the crown, including areas of overbreak in the crown.

Where the lining thickness is insufficient to use a concrete delivery pipe between the shutter and rock surface, concreting ports shall be provided in the crown shutter at intervals of not more than two metres.

Concrete vibrators shall not be run in circumstances likely to draw concrete away from contact with the rock surface in the crown unless pressure is maintained by the concrete pump while vibrators are run. This requirement is of particular importance at the end of a concreting cycle.

4.22.6 Construction Joints

Construction joints shall generally be formed at locations and angles to the line of the tunnel or shaft in a manner approved by the Engineer.

Prior to the concreting of an adjacent section of lining, the surface of the construction joint shall be cleaned of all laitance, loose or defective concrete coatings and foreign material. Cleaning shall be effected by the use of high velocity air water jets and/or sandblasting followed by thorough washing or other means approved by the Engineer.

Before deposition of further concrete, the surface of the existing concrete shall be clean, hard and sound and if required by the Engineer shall be wet without any freestanding water.

If not otherwise indicated on the Drawings or instructed by the Engineer, construction joints shall be sealed with hydrophylic waterstops, placed in a half-depth indentation preformed in the previous end stop shutter, in accordance with Sub-Section 4.14. A polysulphide sealant shall be provided in a cleanly preformed indentation at the inner surface of construction joints in concrete lining to tunnels and shafts.

4.22.7 Location of Embedded Steelwork

Where concrete linings are to be constructed in areas in which steelwork is cast in, careful note shall be made of the exact locations of all steelwork. This information is required so that

holes can be drilled for post-lining grouting to ensure complete filling of the spaces between the excavated surface or rock support layers and the final lining.

The above record will be required whether or not sleeves are provided for grouting.

4.22.8 Grouting Concrete Linings

Not sooner than 28 days after placing the concrete, the interface between the concrete and the surrounding ground shall be grouted to the extent shown on the Drawings and in accordance with the requirements set out in Sub-Section 6.4.2 of the Specification.

4.23 SLIDING FORMWORK

Prior to fabrication or bringing the assembly and auxiliary equipment to the Site, the Contractor shall submit drawings of the complete sliding formwork assembly to the Engineer for acceptance. The drawings shall show full details of the forms, jacking frames, access ladders, hanging platforms, safety rails and curing skirts, as well as details of the jacks and jack layouts.

The Contractor shall be required to submit to the Engineer, before sliding commences, an instruction manual wherein the sliding technique, jacking procedure, methods of keeping the formwork level, procedure to be adopted to prevent bonding of the concrete to the forms and method to release the forms in the event of bonding, the instrumentation and monitoring of the slide, correcting for verticality, twisting and levelness, etc. are described in detail.

The formwork panels shall be inclined to give a small taper, the forms being slightly wider at the bottom than at the top. The taper shall be designed to produce the specified concrete thickness at mid-lift level of the form.

The spacing of the jacks with their jack rods must be so designed that the dead load of the sliding formwork assembly, the frictional load and the mass of materials, personnel and equipment are evenly distributed and within the design capacity of the jacks used.

Concrete sections with dimensions smaller than 200 mm shall not be formed with sliding formwork, unless approved by the Engineer.

During the entire duration of the sliding operations a competent person on the Contractor's staff, who is fully acquainted with the sliding technique and the Contractor's methods of construction shall be in attendance on the sliding platform and in control of the sliding operations.

The Contractor shall give the Engineer 24 hours notice of his intention to commence with a slide. Permission to commence with the slide shall not be given by the Engineer before the sliding formwork assembly is fully operative and the complete stock of all materials required for the slide as well as back-up equipment are on Site.

The Contractor shall ensure that the rate of sliding is such that the concrete at the bottom of the formwork has obtained sufficient strength to support itself and all loads that may be imposed upon it at the time, and that the concrete does not adhere to the sides of the forms.

The sliding operations shall be continuous, without any interruptions, until the full height of the structure is reached. The rate of sliding shall be agreed with the Engineer.

Concrete shall be cast in uniform layers along the formwork so that the top surface of the concrete does not differ by more than 150 mm at any part of the formwork. In addition, the level of the concrete shall never be more than 300 mm below the top of the sliding panel. The working platform must be kept clean and no concrete which has partially dried out may be swept into the formwork.

When the sliding operations are delayed for more than 45 minutes, the Contractor shall prevent adhesion of the setting concrete to the formwork panels by easing the forms or by moving them slightly every 10 minutes, or alternatively, where reversible jacks are used, by lowering the forms by 10 mm to 25 mm. Wherever interruptions occur emergency construction joints shall be formed and treated in accordance with Sub-Section 4.12 and, where appropriate, Sub-Section 4.22.6 Before concreting is restarted, the form shall be adjusted to fit snugly into the hardened concrete so as to avoid steps forming on the exposed concrete surface. When sliding is recommenced, care shall be exercised to prevent the fresh concrete from being lifted off from the old concrete.

4.24 WATER TIGHTNESS TEST FOR CONCRETE WATER TANKS

4.24.1 General

Water tanks testing shall be done according to the method specified below.

The testing of tanks or water containment structures shall confirm to the following standards, as applicable to the project and as modified herein:

i. Reinforced concrete water retaining structures-ACI 350 IR and as specified herein.
ii. Wire wound pre-stressed concrete tanks AWWA D110 or ACI 344 R-W.
iii. Pre-stressed tendon tanks- ACI 344 R-T.
iv. Steel tanks AWWA D100.

If water tanks are not above ground, perform water tightness tests prior to placing backfill around the water tank in order to permit observations and detection of leakage points. Walls may be backfilled prior to testing only when approved in writing by the Engineer. The request to backfill prior to testing shall include a description of the method proposed to detect leakage points after the backfill is in place. Approval place backfill prior testing shall not relive the Contractor of the responsibility for conducting water tightness tests.

a. Inspection:

Inspect the water tank for potential leakage paths such as cracks, voids, etc and repair such paths in compliance with the provisions specified herein.

b. Preparation:

Thoroughly clean the water tank to be tested of dirt, mud and construction debris prior to initiating water tightness tests. The walls, floors and sumps shall be flushed with water to provide a clean surface, ready for testing.

Inlet and outlet pipes not required being operational for the tests might be temporarily sealed or bullheaded prior to testing.

Confirm adequacy of seals around gates and valves and reset or seal as approved by the Engineer. Estimates of gate or valve leakage will not be allowed as adjustments to the measured tank or structure leakage.

c. Conditions for Testing-Concrete Water Tanks:

Do not begin initial filling of concrete water tank until all concrete elements of the water tank have attained the designed compressive strength of the concrete (28 days), nor less than 14 days after all concrete walls or base slabs have been placed.

d. Reports:

Submit to the Engineer water tightness test results for the water tank tested. The report should include the test date, the operating level, level records, test duration, temperature, attendees, and other related information.

Notify the Engineer of the scheduling of tests three working days prior to the tests. The Engineer should attend and monitor any water tightness testing performed on the water tank.

4.24.2 Water Tightness Test

Water tightness test shall be carried out before any internal painting or external isolation of water tank walls.

a. Filling the Water Tanks with Water

The water tank shall be slowly filled with potable water keeping the level in the tank at a maximum height rate of 1.2 metres per 24 hours until the maximum operating level is reached.

If the water tank is divided into two compartments, the water tank shall be slowly filled with potable water keeping the level in both sections of the water tank at the same height. Filling of the water tank shall be done at a maximum rate of 1.2 metres per 24 hours up to the maximum operating level.

If there is any leakage during the test period (24 hours), the tank shall be emptied and the leakage shall be repaired before continuing.

b. Procedure

i. Filling of reinforced concrete water tanks shall not exceed a rate of 1.2m in 24 hours.

ii. Fill unlined (fair face) or partially lined (plastered) concrete water tanks to the maximum operating water surface level and maintain the water at that level for 24 hours.

iii. Measure the drop in water level over the next 72 hours to determine the water volume loss for comparison with the allowable leakage limits (72 hours to minimize water absorption by the concrete during testing process).

iv. Measure and record loss of water volume should be at 24 hours intervals. The loss of volume is usually determined by measuring the drop in water surface elevation, and computing the change volume of the contained water. Measure water surface level at not less than locations at 180° apart and preferably at four locations 90 degrees apart. Record water temperature 450 mm below the water surface when taking the first and last sets of measurements.

v. If all records for the loss of water volume over the 72 hours does not exceed the allowable leakage limits, the leakage should be considered acceptable.

vi. If the leakage (loss of waster volume) in any of the three days exceeds the maximum allowable leakage limits, the leakage test should be extended to a total of five days.

vii. If at the end of the five days the average daily leakage (average loss of volume) does not exceed the maximum allowable limits, the test should be considered acceptable.

viii. If the leakage of the water volume exceeds the maximum allowable leakage limits, leakage should be considered excessive and the tank should be emptied and repaired.

c. Acceptance

The following conditions shall be considered as NOT meeting the criteria for acceptance regardless of the actual loss of water volume from the water tank:

i. Ground water leakage into the water tank through floors, walls, or wall-floor joints.

ii. Water tank which exhibit flowing water from joints, cracks or from beneath the foundation (except for under-drain systems).

iii. Lined concrete water tanks or pre-stressed concrete water tanks on which moisture can be picked up by a dry hand from the exterior surface of the walls.

iv. Damp spots on the exterior wall surfaces of the water tank appears.

The water tightness of concrete tanks should be considered acceptable when loss of water volume is within the allowable leakage limits listed bellow:

i. For unlined (fair face) tanks with a sidewater depth of 7.5 m or less, loss of volume not exceeding 0.10% in 24 hours.

ii. For tanks with lined (plastered) walls and a sidewater depth 9.0 m or less, loss of volume not exceeding 0.06% in 24 hours. Steel diaphragms in concrete walls shall be considered the same as a wall liner.

iii. For completely lined tanks (walls and ceiling), loss of volume not exceeding 0.025% in 24 hours.

d. Open Water Tanks

During the test period, the ambient evaporation of water shall be measured at a location near the water tank in an evaporation pan or by other approved means. Evaporation for local areas measured shall be considered.

If the drop in the tank water surface in a 24 hours period exceeds the normal evaporation of water by 0.1% of the filled total volume, the leakage shall be considered excessive and shall be repaired before continuing.

e. Repairs and Retesting

A water tank failing the water tightness test and not exhibiting visible leakage may be retested after an additional stabilization period of 7 days. Tanks failing this second test shall be repaired prior to further testing.

Water tanks which fail the water tightness test, and water tanks showing visible leakage, shall be repaired in compliance with the provisions specified herein.

Repair and retesting of tanks shall be accomplished at no additional cost to the Employer.

The Contractor shall make all necessary repairs if the tank fails the water tightness test or is otherwise defective. The method of repair shall be subject to prior approval by the Engineer.

1. Minor Concrete Repair:

   The most common repair method for small areas of honeycombed concrete (rock pockets) and other defective concrete is removal and replacement with non-shrink aggregate grout (which may include pea gravel aggregate) bonded to the concrete with an epoxy bonding agent. The minimum strength of material used in the repair shall equal or exceed that specified for the concrete.

   Defective tie hole patches shall be removed and the holes repacked or epoxy injected.

2. Epoxy Injection Grouting:

   - Walls:
     Damp or wet spots on a wall resulting from leakage through the wall shall be repaired with a high-pressure epoxy injection grouting system or other method acceptable to the Engineer. When epoxy grouting is to be performed, a low-viscosity, two-component, water-insensitive, nontoxic epoxy-resin system with an in-line metering and mixing system shall be used. The pumps shall be capable of producing minimum injection pressure of 100 psi (680 kPa). Injection pressure shall be limited to 300 psi (2.1 Mpa) to ensure complete penetration of the defect without damaging the structure. Epoxy shall reach a minimum compressive strength of 6,000 psi (40 MPa) in 24 hours in accordance with the requirements of ASTM D695. An applicator with successful past experience in water structures shall be present on the job at all times while repairs are being made. Work shall be guaranteed against failure of the epoxy bond in the repair areas for a minimum period of one year.

     Any exposed defect receiving epoxy repair shall first be cleaned of dirt, laitance, and other material that might prevent proper bonding. A suitable temporary seal shall then be applied to the surface of the defect to prevent the escape of the epoxy. Entry ports shall be spaced along the seal at intervals not grater than the thickness of the cracked element. The epoxy shall be injected into the crack at the lowest port first, with sufficient pressure to advance the epoxy to an adjacent port, using a small

nozzle held tightly against the port. The operation shall continue until epoxy material begins to extrude from the adjacent port. The original port shall be sealed and the injection shall be repeated in one continuous operation until the crack has been injected with epoxy for its entire length. All ports, including adjacent locations where epoxy seepage occurs, shall be sealed as necessary to prevent drips and runouts. On completion of the injection of the crack, the grout shall be allowed to cure for sufficient time to allow the removal of the temporary seal without any draining or running out of the adhesive epoxy material from the crack. The surface of the crack shall then be finished with the adjacent surfaces and shall show no indentations or evidence of port filling.

- Floors, Piping and Valves:

  Generally the loss of water through the tank floor, piping, and valves is difficult to determine separately. The total water loss shall not exceed the criteria set forth in Sub-Section 4.24.2-c If the loss of water exceeds the criteria, the tank floor shall be inspected for point sources of leakage with the tank full or empty.

  Water loss through floor joints or shrinkage cracks shall be located and the defective sections removed and replaced, or repaired by epoxy injection grouting as specified earlier or by other means acceptable to the Engineer. Any potential point sources of leakage found shall be repaired and the water tightness test repeated.

4.24.3 Measurements

Unless otherwise provided for by specific items in the Bill of Quantities, water tank testing shall not be measured for separate payment but shall be deemed to be subsidiary works, the cost of which is to be included within the other prices for concrete works.

5 PRECAST CONCRETE

5.1 FORMWORK

Moulds for precast units shall comply with the general requirements of Sub-Section 2.

Moulds shall be so constructed that they do not suffer distortion or dimensional changes during use and are tight against loss of cement or fines from the concrete.

Moulds shall be set up on firm foundations so that no settlement occurs under the weight of the fresh concrete.

Moulds shall be constructed so that units may be removed from them without sustaining any damage.

Release agents used for demoulding shall not stain the concrete or affect its properties in any way.

5.2 REINFORCEMENT

Reinforcement in precast units shall comply with the requirements of Sub-Section 3. When preformed cages are used the cages shall be made up on jigs to ensure dimensional accuracy and shall be carefully supported within the mould in such a way that they cannot move when concrete is placed. Reinforcement complying with BS 4449 may be tack welded where bars cross to provide rigidity in the cage but cold worked steel bars shall not be welded.

The concrete cover to reinforcement shall be equal to or greater than the cover stated in the general notes accompanying the Drawings or indicated on the Drawings. Precast members with inadequate cover shall be rejected and removed from Site.

Bars shall be spaced so that the minimum clear distance between them is the maximum nominal aggregate size plus five millimetres but in any case not less than the diameter of the bars.

Bars may be placed in pairs provided that there are no laps in the paired lengths.

5.3 CASTING OF UNITS

Concrete for precast units shall comply with Sub-Section 4, using the class of concrete specified on the Drawings. The concrete in each unit shall be placed in one operation.

The area in which units are cast shall be adequately protected from the weather so that the process is not affected by rain, freezing conditions, sun or drying winds.

5.4 CURING PRECAST UNITS

Requirements for curing shall be generally as set out in Sub-Section 4.

The Contractor shall ensure that units do not suffer any loss of moisture or sudden changes of temperature for at least four days after casting. If a water spray is permitted for curing, the water shall be at a temperature within 5°C of the temperature of the unit being cured.

If the Contractor proposes curing at elevated temperatures, the method shall be subject to the agreement of the Engineer and shall include means whereby units are heated and subsequently cooled evenly without any sudden changes of temperature.

5.5 DIMENSIONAL TOLERANCES

Units shall be accurately formed to the dimensions shown on the Drawings and within the tolerances set out in BS 8110 unless closer tolerances are called for elsewhere in the Contract.

5.6 SURFACE FINISH

The formed faces of precast units shall be finished to Class F3 as set out in Sub-Section 2 unless another class of finish is specified on the Drawings.

Free faces shall be finished to Class U2 unless another class of finish is specified elsewhere.

In cases where a special finish is required a trial panel shall be constructed by the Contractor which after approval by the Engineer shall be kept available for inspection at the place of casting and production units shall thereafter match the approved pattern.

Surfaces of precast units against which concrete is to be placed shall have an exposed aggregate finish.

5.7 HANDLING AND STORAGE OF UNITS

Precast units shall be handled in a manner which will not cause damage of any kind and shall be stored on a hard, impermeable base. Precast units shall be handled and stored so that no stresses shall be induced in excess of those which they will incur in their final positions in the Permanent Works unless they have been designed to resist such stresses.

Units shall be provided with adequate lifting holes or loops, placed in the locations shown on the Drawings or agreed by the Engineer and they shall be lifted only by such holes or loops. Units are to be indelibly marked to indicate the final orientation. Where it is not possible to provide holes or loops, suitable sling positions shall be indicated in paint on the units.

Units shall be marked indelibly with the reference number and date of casting and shall be stacked on suitable packers which will not damage the concrete or stain the surfaces. Reference numbers shall correspond with those shown on placing plans and shall be clearly visible after the unit has been fixed in place. Not more than two packers shall be placed under each unit and these shall be located either at the positions of the permanent support points or in positions such that the induced stresses in the unit will be a minimum.

5.8 PURCHASED UNITS

If the Contractor proposes to purchase precast units from a supplier, he shall ensure that such units comply with the requirements of the Specification and shall carry out any tests which the Engineer may require to check compliance. The Contractor shall provide free facilities for the Engineer to inspect the manufacturer's premises.

Units shall not be obtained from any supplier who refuses free access by the Engineer to the factory to inspect and test materials and workmanship.

5.9 TESTING UNITS

Precast units shall be capable of safely sustaining the loads which they have been designed to carry. If instructed by the Engineer, the Contractor shall subject units selected by the Engineer to load tests simulating the working conditions. Details of such tests shall be agreed between the Engineer and the Contractor.

In the case of units subject to bending loads the test piece shall be supported at full span and a loading equivalent to 125% of the sum of the live and dead loads which were assumed in the design shall be maintained for one hour without the appearance of any signs of distress. The recovery one hour after the removal of load shall be not less than 75% of the full load deflection.

If the unit fails to meet the above requirements, further tests shall be carried out on two more units. If either of these fail the whole batch of units will be rejected.

If the Engineer so requires, a test to destruction shall also be carried out which on units subject to bending shall be as follows:

i. The unit shall be supported at full span and a load applied in increments instructed by the Engineer up to 95% of the designed ultimate load. This load shall be held for 15 minutes without failure of the unit. The deflection at the end of this period shall be not more than 1/40th of the span. The load shall then be further increased until failure occurs.

ii. If the unit fails to sustain the required load for the prescribed period or if the deflection exceeds the specified amount, the Engineer may order two further tests, and if either of these fail, the batch of units which they represent may be rejected.

6 CONCRETE ANCILLARIES

Concrete inserts for the support of cabling, pipework etc. shall be formed from proprietary units approved by the Engineer and formed from hot dip galvanised steel.

7 STANDARDS

The following international standards are applicable for Works covered by this Section of the Specification.

BS 1088 Marine Plywood

BS 1200 Specification for Building Sands from Natural Sources

BS 1370 Specification for Low Heat Portland Cement

BS 1377 Methods of Test for Soils for Civil Engineering Purposes

BS 146 Specification for Blastfurnace Cements with Strength Properties Outside the Scope of BS EN 197-1

BS 1881 Testing Concrete

BS 2499 Hot-applied Joint Sealant Systems for Concrete Pavements

BS 2640 Specification for Class II Oxy-acetylene Welding of Carbon Steel Pipework for Carrying Fluids

BS 3837 Expanded Polystyrene Boards

BS 3892 Pulverized Fuel Ash

BS 4027 Specification for Sulfate-resisting Portland Cement

BS 4254 Specification for Two-part Polysulphide-based Sealants

BS 4449 Specification for Carbon Steel Bars for the Reinforcement of Concrete

BS 4482 Specification for Cold Reduced Steel Wire for the Reinforcement of Concrete

BS 4483 Steel Fabric for the Reinforcement of Concrete

BS 4550 Methods of Testing Cement

BS 4840 Rigid Polyurethane (PUR) Foam in Slab Form

BS 4887 Mortar Admixtures

BS 5075 Concrete Admixtures

BS 5224 Specification for Masonry Cement

BS 5268 Structural Use of Timber

BS 5328 Specification of Concrete

BS 5975 Code of Practice for Falsework

BS 6213 Selection of Construction Sealants

BS 6699 Specification for Ground Granulated Blastfurnace Slag for Use with Portland Cement

BS 7123 Specification for Metal Arc Welding of Steel for Concrete Reinforcement

BS 7973 Spacers and Chairs for Steel Reinforcement and their Specification

BS 7979 Specification for Limestone Fines for Use with Portland Cement

BS 8004 Code of Practice for Foundations

BS 8007 Code of Practice for Design of Concrete Structures for Retaining Aqueous Liquids

BS 8110 Structural Use of Concrete

BS 812 Testing Aggregates

BS 8666 Specification for Scheduling, Dimensioning, Bending and Cutting of Steel Reinforcement for Concrete

BS 882 Specification for Aggregates from Natural Sources for Concrete

EN 1008 Mixing Water for Concrete

EN 1097 Tests for Mechanical and Physical Properties of Aggregates

EN 12350 Testing Fresh Concrete

EN 12390 Testing Hardened Concrete

EN 12620 Aggregates for Concrete

EN 196 Methods of Testing Cement

EN 197 Cement

EN 206 Concrete – Specification, Performance, Production and Conformity

EN 480 Admixtures for Concrete, Mortar and Grout – Test Methods

EN 932 Tests for General Properties of Aggregates

EN 933 Tests for Geometrical Properties of Aggregates

EN 934 Admixtures for Concrete, Mortar and Grout

EN 998 Specification for Mortar for Masonry