GENERAL SPECIFICATION
FOR
CIVIL ENGINEERING WORKS

SECTION 16
CONCRETE AND JOINTS IN CONCRETE
SECTION 16

CONCRETE AND JOINTS IN CONCRETE

PART 1: CONCRETE WORKS

GENERAL

Sprayed concrete 16.01 Sprayed concrete shall comply with Section 7 except as stated in this Section.

Designation of concrete mixes 16.02 (1) Designed mix concrete shall be designated by the grade strength in MPa followed by the nominal maximum aggregate size in mm and the suffix D.

(2) Standard mix concrete shall be designated by the grade strength in MPa followed by the nominal maximum aggregate size in mm and the suffix S.

(3) Designed mix concrete or standard mix concrete of the same grade strength but with different constituents, workability or other properties shall be designated as such by the addition of a suitable description. If the grade of concrete is designated by one number only, the number shall be the grade strength in MPa.

GLOSSARY OF TERMS

Cementitious content 16.03 Cementitious content is the mass of cement per cubic metre of compacted concrete or, if cement and PFA are used as separate constituents, the combined mass of cement and PFA per cubic metre of compacted concrete.

Grade 16.04 Grade is a term used to identify the different concrete mixes in terms of grade strength or in terms of grade strength and nominal maximum aggregate size.

Grade strength 16.05 Grade strength is the compressive strength of concrete stated in the Contract. For designed mix concrete, compliance with the grade strength shall be ascertained in accordance with Clause 16.61.

MATERIALS

Cement 16.06 (1) Cement shall comply with the following:

Portland cement (PC) : BS EN 197-1

(Type CEM I) Strength Class of cement used in structural concrete to be 52.5N, unless otherwise approved by the Engineer.
Sulphate resisting Portland Cement (SRPC) : BS 4027

Portland fly ash (PFAC) cement : BS EN 197-1
(Types CEM II/A-V and CEM II/B-V) Strength Class of cement used in structural concrete to be 42.5N or higher, unless otherwise approved by the Engineer.

(2) The limiting values applicable to acceptance inspection of cement at delivery shall be those given in Table NC.1 of National annex NC of BS EN 197-1

Pulverized Fly Ash (PFA) 16.07 PFA shall comply with BS 3892: Part 1 except that the criterion for maximum water requirement shall not apply.

Aggregates 16.08 (1) Aggregates shall be obtained from a source approved by the Engineer.

(2) Fine aggregate shall be clean, hard and durable crushed rock, or natural sand, complying with BS 882, except that the NOTE in Table 5 of BS 882 shall not apply.

(3) Coarse aggregate shall be clean, hard, durable crushed rock complying with BS 882. The ten percent fines values shall be at least 100 kN. The water absorption shall not exceed 0.8%. The flakiness index shall not exceed 35%.

Water 16.09 (1) Water for concrete and for curing concrete shall be clean fresh water taken from the public supply.

(2) Wash water from concrete mixer washout operations (recycled water) may be used for mixing concrete of grade strength not exceeding 35MPa provided that:

(a) The density of the recycled water shall not exceed 1030 kg/m³.

(b) The limits for the time of setting (h:min), expressed as deviation from those for control mix, shall comply with Table 16.8. The control mix shall be of the same mix design but clean fresh water shall be used.

(c) The chemical limits of the recycled water shall not exceed those specified in Table 16.8.

Admixtures 16.10 (1) Admixtures shall comply with the following:

Pigments for Portland cement and Portland cement products : BS 1014
Accelerating admixtures, retarding admixtures and water-reducing admixtures: BS 5075: Part 1

Superplasticising admixtures: BS 5075: Part 3.

(2) The chloride ion content of admixtures for concrete containing embedded metal or for concrete made with SRPC shall not exceed 2% by mass of the admixture or 0.03% by mass of the cementitious content, whichever is less.

**Curing compound**

16.11 (1) Curing compound shall be a proprietary type approved by the Engineer and shall have an efficiency index of at least 80%. Resin-based curing compound shall not be used unless approved by the Engineer.

(2) Curing compound shall contain a fugitive dye. Curing compounds containing organic solvents shall not be used. The curing compound shall become stable and achieve the specified resistance to evaporation of water from the concrete surface within 60 minutes after application. Curing compound shall not react chemically with the concrete to be cured and shall not crack, peel or disintegrate within one week after application. Curing compound shall degrade completely within three weeks after application and the concrete surface treated shall not impair the bonding of applied finishes.

(3) Curing compound for use on concrete surfaces against which potable or fresh water will be stored or conveyed shall be non-toxic and shall not impart a taste to the water.

**CONCRETE**

**Concrete mix**

16.12 (1) Concrete shall be a designed mix unless the Engineer permits the use of a standard mix. Designed mixes shall be designed by the Contractor.

(2) Unless otherwise permitted by the Engineer, the minimum design slump value for designed mix concrete for reinforced elements, after the addition of superplasticiser if used, shall be 75 mm. Should the Contractor wish to use designed mix concrete with a design slump value less than 75 mm in reinforced elements, the Engineer may require the Contractor to demonstrate that such concrete can be satisfactorily placed and compacted in trial sections simulating the appropriate sections of the Works.

(3) Cement, PFA, aggregates, water and admixtures for concrete shall comply with Clauses 16.06 to 16.10. All-in aggregate shall not be used.

(4) SRPC shall only be used if stated in the Contract. PFA shall not be used with SRPC.

(5) PFA shall not be used in addition to PFAC.

(6) PFA shall be used in concrete of all pile caps and substructure construction where the concrete member is thicker than 750 mm.
Chloride content of concrete

16.13 The maximum total chloride content of concrete, expressed as a percentage relationship between the chloride ion and the cementitious content by mass in the concrete mix, shall be as stated in Table 16.1. If the concrete is of more than one of the types stated, then the lower value of maximum chloride content shall apply.

Table 16.1: Maximum total chloride content of concrete

<table>
<thead>
<tr>
<th>Type of concrete</th>
<th>Maximum total chloride content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prestressed concrete. Steam-cured structural Concrete</td>
<td>0.1</td>
</tr>
<tr>
<td>Concrete with reinforcement or other embedded metal</td>
<td>0.35</td>
</tr>
<tr>
<td>Concrete made with SRPC</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Cementitious content of designed mix concrete

16.14 (1) The minimum cementitious content of designed mix concrete of Grade 20 or above using 20 mm nominal maximum aggregate size shall be as stated in Table 16.2. The minimum cementitious contents shall be increased by 40 kg/m³ for 10 mm nominal maximum aggregate size and decreased by 30 kg/m³ for 40 mm nominal maximum aggregate size.

(2) Unless otherwise approved by the Engineer, the maximum cementitious content of designed mix concrete for water retaining structures and water tight structures shall be 400 kg/m³ for concrete containing PC and shall be 450 kg/m³ for concrete containing either PC and PFA or PFAC. Unless otherwise approved by the Engineer, the maximum cementitious content of designed mix concrete other than for water retaining structures and water tight structures shall be 550 kg/m³.

(3) The cementitious content of designed mix concrete may be varied during routine production at the discretion of the Contractor by an amount not exceeding 20 kg/m³, provided that the total cementitious content is not less than the specified minimum value and does not exceed the specified maximum value.

(4) When PFA is incorporated in the concrete as a separate material, its proportion shall not exceed 35% of the total cementitious content for normal concrete. If other conditions apply, particulars of proposed changes to the proportion of PFA shall be submitted to the Engineer for approval.

(5) When PFA is used in construction of pile caps and substructures, the PFA content shall constitute at least 25% of the cementitious content in the concrete.
Table 16.2: Minimum cementitious content of designed mix concrete of Grade 20 or greater with 20 mm nominal maximum aggregate size

<table>
<thead>
<tr>
<th>Grade strength (MPa)</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimum cementitious content (kg/m³)</td>
<td>270</td>
<td>290</td>
<td>310</td>
<td>330</td>
<td>350</td>
<td>375</td>
<td>400</td>
</tr>
</tbody>
</table>

**Standard mix concrete** 16.15 Standard mix concrete shall comply with the following requirements:

(a) Cement shall be PC or PFAC.

(b) The total mass of dry aggregate to be used with 100 kg of PC or with 110 kg of PFAC shall be as stated in Table 16.3.

(c) The percentage by mass of fine aggregate to total aggregate shall be as stated in Table 16.4.

(d) Admixtures other than water-reducing admixtures shall not be used unless permitted by the Engineer.

Table 16.3: Mass of total aggregate for standard mix concrete

<table>
<thead>
<tr>
<th>Grade strength (MPa)</th>
<th>Nominal maximum aggregate size (mm)</th>
<th>40</th>
<th>20</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Slump value (mm)</td>
<td>85-170</td>
<td>75-150</td>
<td>65-130</td>
</tr>
<tr>
<td></td>
<td>Mass of total aggregate (kg)</td>
<td>800</td>
<td>690</td>
<td>-</td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>550</td>
<td>500</td>
<td>400</td>
</tr>
<tr>
<td>20</td>
<td></td>
<td>490</td>
<td>440</td>
<td>360</td>
</tr>
<tr>
<td>25</td>
<td></td>
<td>440</td>
<td>380</td>
<td>300</td>
</tr>
<tr>
<td>30</td>
<td></td>
<td>440</td>
<td>380</td>
<td>300</td>
</tr>
</tbody>
</table>
Table 16.4: Percentage by mass of fine aggregate to total aggregate for standard mix concrete

<table>
<thead>
<tr>
<th>Grade strength (MPa)</th>
<th>Grading of fine aggregate (BS 882: Table 5)</th>
<th>Nominal maximum aggregate size (mm)</th>
<th>40</th>
<th>20</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>C, M or F</td>
<td>Percentage by mass of fine aggregate to total aggregate (%)</td>
<td>30 - 45</td>
<td>35 - 50</td>
<td>-</td>
</tr>
<tr>
<td>20, 25 or 30</td>
<td>C</td>
<td></td>
<td>30 - 40</td>
<td>35 - 45</td>
<td>45 - 55</td>
</tr>
<tr>
<td></td>
<td>M</td>
<td></td>
<td>25 - 35</td>
<td>30 - 40</td>
<td>40 - 50</td>
</tr>
<tr>
<td></td>
<td>F</td>
<td></td>
<td>25 - 30</td>
<td>25 - 35</td>
<td>35 - 45</td>
</tr>
</tbody>
</table>

No-fines concrete 16.16 No-fines concrete shall comply with the following requirements:

(a) Cement shall be PC or PFAC.

(b) The nominal maximum aggregate size shall be 20 mm. Not more than 15% by mass shall be retained on a 20 mm BS test sieve and not more than 10% by mass shall pass a 10 mm BS test sieve.

(c) The aggregate:cement ratio by mass shall be at least 10 and shall not exceed 15.

(d) The cementitious content shall be such that each particle of aggregate is coated with cement paste but the compacted concrete has an open texture that permits the flow of water through the hardened concrete.

SUBMISSIONS

Particulars of materials for concrete 16.17 (1) The following particulars of the proposed cement, PFA and aggregates shall be submitted to the Engineer:

(a) A certificate not older than 6 months for each type of cement showing the manufacturer's name, the date and place of manufacture and showing that the cement complies with the requirements stated in the Contract and including results of tests for:
   - Composition
   - Chemical requirement
   - Compressive strength at 2, 7 and 28 days
   - Initial setting time
   - Soundness
(b) A certificate not older than 6 months for PFA showing the source of the PFA and showing that the PFA complies with the requirements stated in the Contract and including results of tests for:
- Chemical composition
- Fineness
- Moisture content

(c) A certificate not older than 6 months for each nominal maximum aggregate size showing the source of the aggregate and showing that the aggregate complies with the requirements stated in the Contract and including results of tests for:
- Grading
- Silt content
- Chloride content
- Flakiness index of coarse aggregate.
- Ten percent fines value
- Water absorption

(2) The following particulars of the proposed admixtures shall be submitted to the Engineer:

(a) Manufacturers’ literature,
(b) Description of physical state, colour and composition,
(c) Recommended storage conditions and shelf life,
(d) Method of adding to the concrete mix,
(e) Any known incompatibility with other admixtures or cement,
(f) Recommended dosage,
(g) Effects of under-dosage and over-dosage, and
(h) A certificate not older than 6 months for each type of admixture showing the manufacturer’s name, the date and place of manufacture and showing that the admixture complies with the requirements stated in the Contract and including results of tests for:
- Uniformity
- Chloride content.

(3) The following particulars of the proposed curing compound shall be submitted to the Engineer:

(a) Manufacturer’s literature,
(b) Description of physical state, colour and composition,
(c) Recommended storage conditions and shelf life,
(d) Method of application,
(e) Recommended rate of application, and

(f) A certificate showing the manufacturer's name, the date and place of manufacture and showing that the curing compound complies with the requirements stated in the Contract and including results of tests for efficiency index.

(4) If recycled water is used for mixing concrete, results of the tests specified in Clause 16.51 and Table 16.8 shall be submitted to the Engineer.

(5) The particulars, including certificates, shall be submitted to the Engineer at least 14 days before the first delivery of the material to the Site, and thereafter each time the source is changed.

**Particulars of concrete mix**

16.18 (1) The following particulars of each proposed designed concrete mix shall be submitted to the Engineer:

(a) Quantity of each constituent per batch and per cubic metre of compacted concrete, with required tolerances on quantities of aggregates to allow for minor variations in grading, silt content etc. The maximum permitted variation in the quantity of fine aggregate shall be ± 20 kg of fine aggregate per 100 kg of cement.

(b) Grading of coarse and fine aggregates,

(c) Workability after the addition of superplasticisers, in terms of designed slump value or designed flow value,

(d) Method of placing concrete,

(e) Method of controlling the temperature of the concrete, if required,

(f) Test or trial mix data for designed mix concrete of the same grade and with similar constituents and properties, if available, and

(g) Test data for designed mix concrete of the same or other grade produced in the plant or plants proposed to be used, if available.

(2) The particulars shall be submitted to the Engineer for information at least 7 days before trial mixes are made or, if trial mixes are not required, at least 7 days before the mix is placed in the permanent work.

**Particulars of ready-mixed concrete supplier**

16.19 The name of the suppliers and the location of each plant, including a back-up plant, from which the Contractor proposes to obtain ready-mixed concrete shall be submitted to the Engineer at least 14 days before trial mixes are made or, if trial mixes are not required, at least 14 days before the ready-mixed concrete is placed in the permanent work.

**Particulars of batching and mixing plant**

16.20 Particulars of the proposed batching and mixing plant to be used on the Site, including a layout plan and the output of the plant, shall be submitted to the Engineer at least 7 days before the plant is delivered to the Site.
16.21 (1) The following particulars of the proposed precast concrete units shall be submitted to the Engineer:

(a) Details of precasting yards,

(b) A certificate showing the manufacturer's name, the date and place of manufacture, the identification numbers of the precast concrete units and including results of tests for:
   - Compressive strength of concrete cubes at 28 days
   - Routine tests, including loading tests, carried out at the precasting yards,

(c) Details of lifting points and methods of handling, and

(d) Procedure for testing precast units.

(2) The particulars, other than certificates, shall be submitted to the Engineer at least 14 days before the first delivery of the precast concrete units to the Site. The certificates shall be submitted for each batch of precast concrete units delivered to the Site.

16.22 Particulars of the proposed positions and details of construction joints in concrete which are not stated in the Contract shall be submitted to the Engineer for approval at least 14 days before the relevant elements are concreted.

TRIALS

16.23 (1) Trial mixes are not required for designed mix concrete of Grade 20 and below, or for standard mix concrete.

(2) If test data for designed mix concrete of the proposed grade and with similar constituents and properties and produced in the plant or plants proposed for being used are submitted in accordance with Clause 16.18, and are acceptable to the Engineer, no trials for that designed mix will be required.

(3) If test data for designed mix concrete of the proposed grade and with similar constituents and properties produced in plant other than that proposed to be used are submitted in accordance with Clause 16.18, and are acceptable to the Engineer, the Engineer may require Plant Trials to be carried out in accordance with Clause 16.24.

(4) If test data for designed mix concrete produced in the plant or plants proposed to be used, but of a grade or with constituents and properties other than those proposed, are submitted in accordance with Clause 16.18, and are acceptable to the Engineer, the Engineer may require Laboratory Mix Trials to be carried out in accordance with Clause 16.25.

(5) If no test data for designed mix concrete are submitted or if test data submitted in accordance with Clause 16.18 do not in the opinion of the Engineer demonstrate the suitability of the proposed plant and mix design, the Engineer may require both Plant Trials and Laboratory Mix Trials in accordance with Clauses 16.24 and 16.25 respectively.
(6) Plant Trials and Laboratory Mix Trials shall be completed at least 35 days before the concrete mix is placed in the permanent work.

(7) The Contractor shall inform the Engineer at least 24 hours before conducting Plant Trials or Laboratory Mix Trials.

**Plant Trials**

16.24

(1) Plant Trials shall be made using the plant or plants proposed and the mix designs and constituents submitted to the Engineer.

(2) One batch of concrete of a proposed designed mix shall be made on each of three days in each plant proposed to be used. The batch shall be at least 60% of the mixer's nominal capacity. If the concrete is batched in a central plant and mixed in a truck mixer, three different truck mixers shall be used.

(3) Three samples of concrete shall be provided from each batch at approximately 1/6, 1/2 and 5/6 of the discharge from the mixer. Each sample shall be of sufficient size to perform a slump test or a flow table test, and make two test cubes. The method of sampling shall be as stated in CS1.

(4) Each sample taken in accordance with Clause 16.24(3) shall be tested to determine its slump value or its flow value in accordance with CS1.

(5) Two test cubes shall be made from each sample taken in accordance with Clause 16.24(3) and stored, cured and tested to determine the compressive strength at 28 days in accordance with CS1.

(6) The size of the test cube shall be 100 mm for concrete with the maximum aggregate size not exceeding 20 mm and shall be 150 mm with the maximum aggregate size exceeding 20 mm.

**Laboratory Mix Trials**

16.25

(1) Laboratory Mix Trials shall be made in the Contractor's laboratory using the mix designs and constituents submitted to the Engineer.

(2) Laboratory Mix Trials shall be carried out in accordance with Section 11 of CS1. Three separate batches shall be made, each of sufficient size to provide samples for two slump tests or two flow table tests, and to make six test cubes.

(3) Two slump tests or two flow table tests in accordance with CS1 shall be performed on separate specimens from each batch of Laboratory Trial Mix concrete.

(4) Six test cubes shall be made from each batch of Laboratory Trial Mix concrete, stored, cured and tested for compressive strength at 28 days in accordance with CS1.

(5) The size of the test cube shall be 100 mm for concrete with the maximum aggregate size not exceeding 20 mm and shall be 150 mm with the maximum aggregate size exceeding 20 mm.
The results of tests on concrete taken from Plant Trials in accordance with Clause 16.24 shall comply with the following requirements:

(a) The average of the nine slump values shall be within 20mm or 25%, whichever is the greater, of the designed slump value. The average of the nine flow values shall be within +/- 50mm of the designed flow value.

(b) The range of the three slump values for each batch of concrete shall not exceed 20% of the average of the three slump values for that batch. For flow table tests, the range of the three flow values for each batch of concrete shall be within 70mm.

(c) The average compressive strength at 28 days of the 18 test cubes shall exceed the Grade strength by at least 12 MPa for 100 mm test cubes or 10 MPa for 150 mm test cubes. The compressive strength of each individual test cube shall exceed the Grade strength by at least 5 MPa for 100 mm test cubes or 4 MPa for 150 mm test cubes.

(d) The range of the compressive strength of the six test cubes from each batch of concrete shall not exceed 20% of the average compressive strength of the six test cubes from that batch.

(1) When test data relating to the proposed plant or plants submitted in accordance with Clause 16.18 show that the plant standard deviation exceeds 5.5 MPa for 100 mm test cubes or 5 MPa for 150 mm test cubes, or in the absence of acceptable data, the results of tests on Laboratory Mix Trial concrete shall comply with the following requirements:

(a) The average of the six slump values shall be within 20mm or 25%, whichever is the greater, of the designed slump value. The average of the six flow values shall be within +/- 50mm of the designed flow value.

(b) The average compressive strength at 28 days of the 18 test cubes shall exceed the Grade strength by at least 14 MPa for 100 mm test cubes or 12 MPa for 150 mm test cubes, and the compressive strength of each individual test cube shall exceed the Grade strength by at least 7 MPa for 100 mm test cubes or 6 MPa for 150 mm test cubes.

(2) When test data relating to the proposed plant or plants submitted in accordance with Clause 16.18 show that the plant standard deviation does not exceed 5.5 MPa for 100 mm test cubes or 5 MPa for 150 mm test cubes and the data are acceptable to the Engineer, the results of tests on Laboratory Mix Trial concrete shall comply with the following requirements:

(a) The average of the six slump values shall be within 20 mm or 25%, whichever is the greater, of the designed slump value. The average of the six flow values shall be within +/- 50mm of the designed flow value.

(b) The average compressive strength at 28 days of the 18 test cubes shall exceed the Grade strength by at least 10 MPa for 100 mm test cubes or 8 MPa for 150 mm test cubes, and the compressive strength of each individual test cube shall exceed the Grade...
strength by at least 3 MPa for 100 mm test cubes or 2 MPa for 150 mm test cubes.

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<td>16.29</td>
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<td>Approved concrete mix</td>
<td>16.30</td>
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<td>Commencement of concreting</td>
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<td>Changes in materials and methods of construction</td>
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**HANDLING AND STORAGE OF MATERIALS**

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</thead>
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<td>16.33</td>
</tr>
<tr>
<td>Handling and storage of aggregates</td>
<td>16.34</td>
</tr>
</tbody>
</table>
(2) Different types and sizes of aggregates shall be stored in separate hoppers or in separate stockpiles. The stockpiles shall have well drained concrete floors and shall have dividing walls of sufficient height to keep the different aggregates separate.

<table>
<thead>
<tr>
<th>Storage of admixtures and curing compounds</th>
<th>16.35</th>
</tr>
</thead>
<tbody>
<tr>
<td>Admixtures and curing compounds shall be stored in sealed containers marked to identify the contents and protected from exposure to conditions that may affect the material. The materials shall be stored in accordance with the manufacturers’ recommendations and shall not be used after the recommended shelf life has been exceeded.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Handling and storage of precast concrete units</th>
<th>16.36</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) The identification number, date of casting and lifting points shall be marked on precast concrete units in a manner agreed by the Engineer.</td>
<td></td>
</tr>
<tr>
<td>(2) Precast concrete units shall be lifted and supported only at the designed lifting points and shall not be subjected to rough handling, shock loading or dropping.</td>
<td></td>
</tr>
<tr>
<td>(3) Precast concrete units shall be stored on a levelled, well drained and maintained hard-standing ground on level supports and in a manner that will not result in damage or deformation to the units or in contamination of the units. Precast concrete units and the lifting points shall be protected from damage/rusting and damaged units shall not be used in the permanent works unless permitted by the Engineer.</td>
<td></td>
</tr>
</tbody>
</table>

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**BATCHING AND MIXING CONCRETE**

<table>
<thead>
<tr>
<th>Batching concrete</th>
<th>16.37</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Measuring and weighing equipment for batching concrete shall be maintained in a clean, serviceable condition. The equipment shall be zeroed daily and calibrated when the equipment is set up on the Site and at a frequency of at least once per month. The accuracy of the measuring equipment shall be within 3% of the quantity of cementitious materials, total aggregates or water being measured and within 5% of the quantity of admixtures being measured.</td>
<td></td>
</tr>
<tr>
<td>(2) The quantities of cement, PFA and fine and coarse aggregate shall be measured by mass except that cement supplied in bags may be measured by using a whole number of bags in each batch. The mass of aggregates shall be adjusted to allow for the free moisture content of the aggregates.</td>
<td></td>
</tr>
<tr>
<td>(3) Separate weighing equipment shall be used for cementitious material and aggregates.</td>
<td></td>
</tr>
<tr>
<td>(4) The quantity of water shall be adjusted for the free moisture content of the aggregates and shall be measured by mass or volume.</td>
<td></td>
</tr>
<tr>
<td>(5) Liquid admixtures shall be measured by mass or volume and powdered admixtures shall be measured by mass.</td>
<td></td>
</tr>
</tbody>
</table>
Mixing concrete 16.38

(1) The quantities of concrete mixed and the speed of operation of a mixer shall comply with the manufacturer's recommendations.

(2) A mixer shall not be loaded in excess of its rated capacity and shall be emptied before being re-charged. A mixer that has been out of use for more than 30 minutes shall be cleaned before fresh concrete is mixed in it. Mixers shall be cleaned whenever there is a change in the type of cement being used.

(3) Mixing times or the number and rate of revolutions of mixer drums shall not be less than those recommended by the manufacturer unless it is demonstrated in the production of concrete that a shorter time or fewer or slower revolutions are adequate. Constituents shall be thoroughly mixed and admixtures shall be uniformly distributed throughout the concrete.

(4) Water shall be added to truck mixed concrete at the batching plant and shall not be added in transit. Water shall not be added at the Site unless approved by the Engineer.

(5) Water shall not be added to partially hardened concrete.

TRANSPORTATION OF CONCRETE

Transportation of concrete 16.39

(1) Concrete shall not be transported in a manner that will result in contamination, segregation, loss of constituents or excessive evaporation.

(2) Concrete batched off the Site shall be transported to the Site in purpose-made agitators operating continuously or in truck mixers.

RECORDS OF CONCRETE

Records of concrete 16.40

(1) Delivery notes shall be provided for each delivery of concrete to the Site. The delivery notes shall be kept on the Site and shall be available for inspection by the Engineer at all times. Delivery notes shall contain the following details:

(a) Serial number of delivery note,

(b) Date,

(c) Name and location of batching and mixing plant,

(d) Registration number of delivery vehicle,

(e) Name of purchaser,

(f) Name and location of the Site,

(g) Designation of concrete mix and approved slump value or approved flow value,

(h) Sources of constituents,

(i) Quantity of concrete, and
(j) Time of introduction of water to the concrete.

(2) Records of concreting operations shall be kept by the Contractor on the Site and shall be available for inspection by the Engineer at all times. Records shall contain the following details:

(a) Date,

(b) Designation of concrete mix and approved slump value or approved flow value,

(c) Total quantity of each concrete mix produced that day,

(d) Serial number of delivery note,

(e) Arrival time of delivery vehicle,

(f) Time of completion of discharge,

(g) Quantity of water added at the Site,

(h) Position where concrete is placed,

(i) Results of flow table tests or slump tests,

(j) Details of test cubes made, and

(k) Temperature of concrete if a restriction on the temperature is stated in the Contract.

PLACING AND COMPACTING CONCRETE

Placing concrete 16.41

(1) The permission of the Engineer shall be obtained before concrete is placed in any part of the permanent work. If placing of concrete is not started within 24 hours of permission having been given, permission shall again be obtained from the Engineer. The Contractor shall inform the Engineer before concreting starts and shall allow the Engineer sufficient time to inspect the work that is to be concreted.

(2) Concrete shall be placed and compacted in its final position within 2½ hours of the introduction of cement to the concrete mix.

(3) Concrete that in the opinion of the Engineer is no longer sufficiently workable shall not be placed in the permanent work.

(4) Concrete shall not be placed in water other than by tremie or in bags.

(5) Concrete shall be placed as close as practicable to its final position and shall not be moved into place by vibration. Trunking or chutes shall be used to place concrete which will fall more than 2.7 m unless otherwise permitted by the Engineer. Trunking or chutes, where being used, shall be clean and used in such a way to avoid segregation and loss of constituents of the concrete mix.
(6) Concrete shall be placed in such a manner that the formwork, reinforcement or built-in components are not displaced.

(7) Unless otherwise permitted by the Engineer, concrete other than concrete placed by tremie shall be placed in horizontal layers to a compacted depth of not more than 450 mm if internal vibrators are used and to a compacted depth of not more than 150 mm in other cases.

(8) Concrete shall be placed continuously within the element to be concreted. Fresh concrete shall not be placed against concrete that has been in position for more than 30 minutes unless in the opinion of the Engineer the concrete already placed is sufficiently workable and the permission of the Engineer has been obtained. If permission is not obtained, a construction joint shall be formed as stated in Clause 16.45. Concrete shall not be placed against the concrete already placed for at least 24 hours unless permitted by the Engineer.

**Placing concrete by pumping**

16.42

(1) Concrete pumps shall be operated and maintained in accordance with the manufacturer’s recommendations. The pumps and pipelines shall be maintained in a clean condition. Internal surfaces of pipelines shall not be aluminium. Joints in pipelines shall be tightly fixed and shall not permit grout loss.

(2) Concrete pumps shall be positioned such that pipelines are as short and straight as practicable and require as little repositioning as practicable. Bends in pipelines shall be arranged in such a manner that the concrete, formwork, reinforcement or built-in components are not disturbed.

(3) Pipelines shall be lubricated by passing cement grout or concrete through the pipeline before the concrete is pumped. The initial discharge of pumped concrete shall not be placed in the permanent work.

**Placing concrete by tremie**

16.43

(1) Tremies used to place concrete shall be securely supported in position and the joints shall be watertight. A temporary seal of a type agreed by the Engineer shall be used to keep the water and the concrete separate at the start of concreting. Concrete for tremie placing shall be self-compactng, free flowing and cohesive.

(2) After the concrete is flowing, the tremie shall be raised in a manner agreed by the Engineer. The lower end of the tremie shall be kept immersed in the concrete to a depth of at least 1 m. Water, mud and other deleterious material shall be prevented from entering the tremie after concreting has started.

(3) If the tremie becomes blocked or is removed from the concrete, concreting shall be stopped immediately unless otherwise permitted by the Engineer. Concreting shall not recommence for at least 24 hours unless permitted by the Engineer. Contaminated concrete shall be removed before concreting recommences.

(4) Concrete placed by tremie shall be placed above the specified level by an amount that is sufficient to allow for the removal of contaminated concrete. Contaminated concrete shall be removed.
Compacting concrete 16.44

1. Concrete shall be compacted to form a dense homogeneous mass.

2. Unless otherwise permitted by the Engineer, concrete shall be compacted by means of internal vibrators of suitable diameter. A sufficient number of vibrators shall be maintained in serviceable condition on the Site to ensure that spare equipment is available in the event of breakdown.

3. Vibrators shall be used in such a manner that vibration is applied continuously and systematically during placing of the concrete until the expulsion of air has practically ceased. Vibrators shall not be used in a manner that will result in segregation. Internal vibrators shall be inserted to the full depth of the concrete placed and shall be withdrawn slowly.

4. Vibration shall not be applied by way of the reinforcement, and contact between internal vibrators and formwork, reinforcement or built-in components shall be avoided as far as possible. Concrete shall be vibrated in such a manner that the formwork, reinforcement or built-in components will not be displaced.

5. Concrete that has been in position for more than 30 minutes shall not be vibrated except as stated in Clause 16.41(8).

6. No-fines concrete shall be compacted using a minimum amount of punning.

Construction joints 16.45

1. Construction joints in concrete shall be formed only at the specified positions and by the specified method unless otherwise approved by the Engineer. The position and details of construction joints which are not stated in the Contract shall be arranged in such a manner that the possibility of the occurrence of shrinkage cracks is minimized.

2. Construction joints shall be normal to the axis or plane of the element being constructed unless otherwise permitted by the Engineer.

3. Waterstops shall be provided at construction joints in water retaining structures and watertight structures.

4. Laitance and loose material shall be removed from the surface of construction joints and the aggregate shall be exposed by a method agreed by the Engineer. The work shall be carried out as soon as practicable after the concrete has hardened sufficiently for the cement matrix to be removed without disturbing the coarse aggregate. The surface of the construction joint shall be cleaned after the matrix has been removed.

5. The surface of the construction joint shall be clean and dry when fresh concrete is placed against it.
Curing concrete 16.46 (1) Concrete shall be protected against harmful effects of weather, running water and drying out by one of the following methods:

   Method 1: A liquid curing compound shall be applied to the concrete surface by a low-pressure spray until a continuous visible covering is achieved. The application rate shall be applied as recommended by the manufacturer. For textured surfaces and fluted surfaces, the application rate shall be adjusted to ensure that full covering is achieved. Covering the adjoining reinforcement or formwork shall be avoided.

   Method 2: The concrete surface shall be covered with hessian, sacking, canvas or other absorbent material agreed by the Engineer or with a layer of fine aggregate at least 25 mm thick. The hessian, sacking, canvas, absorbent material or fine aggregate shall be kept constantly wet.

   Method 3: The concrete surface shall be covered with polyethylene sheeting. Concrete surfaces which have become dry shall be thoroughly wetted before the sheeting is placed.

   Method 4: Unformed concrete surfaces shall be covered with polyethylene sheeting until the concrete has hardened sufficiently for water curing to be carried out. Water curing shall be carried out by spraying the concrete surface continuously with cool water or by ponding immediately after the sheeting is removed. If in the opinion of the Engineer water curing is impracticable, Method 2 shall be used instead of water curing.

(2) Method 1 shall not be used on concrete surfaces against which concrete will be placed or which will have a Class T1 finish or which will be painted or tiled.

(3) Method 1, 2, 3 or 4 shall be carried out on unformed concrete surfaces immediately after the concrete has been compacted and finished. Method 1, 2 or 3 shall be carried out on formed concrete surfaces immediately after the formwork has been removed.

(4) Polyethylene sheeting shall be impermeable and shall have a nominal thickness of 0.125 mm.

(5) Hessian, sacking, canvas, absorbent material and polyethylene sheeting shall be lapped and securely held in position in such a manner that the concrete surface will not be damaged.

(6) Cold water shall not be applied to concrete surfaces or formwork intermittently in large quantities.
(7) The different methods of protection shall be maintained for the minimum periods stated in Table 16.5 after the concrete has been placed. The minimum periods may be reduced by the number of days during which formwork is left in position.

Table 16.5: Minimum periods of protection for concrete

<table>
<thead>
<tr>
<th>Type of structure</th>
<th>Method of protection</th>
<th>Minimum period of protection (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Concrete not containing PFA or PFAC</td>
</tr>
<tr>
<td>Water retaining structures and water tight structures</td>
<td>1, 2, 3 or 4</td>
<td>7</td>
</tr>
<tr>
<td>Others</td>
<td>1, 2, 3 or 4</td>
<td>7</td>
</tr>
</tbody>
</table>

**INSTALLATION OF PRECAST CONCRETE UNITS**

16.47 (1) Contact surfaces between in-situ concrete and precast concrete units shall be prepared as stated in the Contract. Dimensional tolerances shall be checked before the precast concrete units are lifted into position.

(2) Temporary supports and connections shall be provided as soon as practicable during installation of precast concrete units.

(3) Final structural connections shall be completed as soon as practicable after the precast concrete units have been installed.

(4) Levelling devices that have no load bearing function in the finished structure shall be slackened, released or removed after the precast concrete units have been installed.

**LOADING OF CONCRETE**

16.48 (1) Loads which will induce a compressive stress in the concrete exceeding one-third of the compressive strength of the concrete at the time of loading or exceeding one-third of the grade strength, whichever is less, shall not be applied to concrete. Allowance shall be made for the weight of the concrete in determining the loading. The strength of the concrete and the stresses produced by the loads shall be assessed by a method agreed by the Engineer.

(2) Loads from materials not forming part of the permanent work or from construction plant or other vehicles shall not be applied to no-fines concrete.
TESTING: CEMENT, PFA, AGGREGATE, ADMIXTURE,
CURING COMPOUND, RECYCLED WATER

Batch: cement, PFA, aggregate, admixture, curing compound

16.49 A batch of cement, PFA, aggregate, admixture or curing compound is any quantity of cement, PFA, aggregate, admixture or curing compound of the same type, manufactured or produced at the same time in the same place, covered by the same certificates and delivered to the Site, or stored at the ready-mixed concrete plant, at any one time.

Samples: cement, PFA, aggregate, admixture, curing compound

16.50 (1) One sample of each type of cement, PFA, aggregate, admixture and curing compound shall be provided at the same time as particulars of the material are submitted to the Engineer.

(2) The size of each sample and the method of sampling shall be as stated in Table 16.6.

Testing: cement, PFA, aggregate, admixture, curing compound, recycled water

16.51 (1) Each sample of cement, PFA, aggregate, admixture and curing compound shall be tested to determine the properties stated in Table 16.7.

(2) The method of testing shall be as stated in Table 16.7.

(3) The maximum total chloride content of concrete shall be determined on the basis of the results of tests for chloride content of each constituent.

(4) The sampling and testing for acceptance inspection at delivery shall be as stated in National annex NC of BS EN 197-1. The methods of taking and preparing samples of cement shall be as stated in BS EN 196-7.

(5) If recycled water is used for mixing concrete, tests shall be carried out according to the methods and frequency stated in Table 16.8.

Table 16.6: Size of samples and method of sampling cement, PFA, aggregate, admixture and curing compound

<table>
<thead>
<tr>
<th>Material</th>
<th>Size of sample</th>
<th>Method of sampling</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>20 kg</td>
<td>BS EN 196-7</td>
</tr>
<tr>
<td>PFA</td>
<td>20 kg</td>
<td>BS 4550:Part 1</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>25 kg</td>
<td>BS 812: Part 102</td>
</tr>
<tr>
<td>Fine aggregate</td>
<td>10 kg</td>
<td>BS 812: Part 102</td>
</tr>
<tr>
<td>Admixture (powdered)</td>
<td>1 kg</td>
<td>BS 5075: Part 1</td>
</tr>
<tr>
<td>Admixture (liquid)</td>
<td>1 L</td>
<td>BS 5075: Part 1</td>
</tr>
<tr>
<td>Curing compound</td>
<td>5 L</td>
<td>BS 5075: Part 1</td>
</tr>
</tbody>
</table>
Table 16.7: Methods of testing cement, PFA, aggregate, admixture and curing compound

<table>
<thead>
<tr>
<th>Material</th>
<th>Property</th>
<th>Method of testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC, SRPC, PFAC</td>
<td>Composition</td>
<td>BS EN 197-1</td>
</tr>
<tr>
<td></td>
<td>Chemical properties</td>
<td>BS EN 196-2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>BS EN 196-21</td>
</tr>
<tr>
<td></td>
<td>Compressive strength at 2, 7 and</td>
<td>BS EN 196-1</td>
</tr>
<tr>
<td></td>
<td>28 days</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Initial setting time</td>
<td>BS EN 196-3</td>
</tr>
<tr>
<td></td>
<td>Soundness</td>
<td>BS EN 196-3</td>
</tr>
<tr>
<td>PFA</td>
<td>Chemical composition</td>
<td>By BS 3892:Part 1</td>
</tr>
<tr>
<td></td>
<td>Fineness</td>
<td>BS 3892: Part 1</td>
</tr>
<tr>
<td></td>
<td>Moisture content</td>
<td></td>
</tr>
<tr>
<td>Coarse aggregate, fine aggregate</td>
<td>Grading</td>
<td>BS 812: Part 103</td>
</tr>
<tr>
<td></td>
<td>Silt content</td>
<td>BS 812: Part 1</td>
</tr>
<tr>
<td></td>
<td>Chloride content</td>
<td>BS 812: Part 117</td>
</tr>
<tr>
<td>Coarse aggregate</td>
<td>Flakiness index</td>
<td>BS 812: Part 105.1</td>
</tr>
<tr>
<td></td>
<td>Ten percent fines</td>
<td>BS 812: Part 111</td>
</tr>
<tr>
<td></td>
<td>Water absorption</td>
<td>BS 812: Part 2</td>
</tr>
<tr>
<td>Admixture</td>
<td>Chloride content</td>
<td>BS 5075: Part 1</td>
</tr>
<tr>
<td>Curing compound</td>
<td>Efficiency index</td>
<td>Appendix 16.1</td>
</tr>
</tbody>
</table>
### Table 16.8: Recycled water testing for each batching plant

<table>
<thead>
<tr>
<th>Description</th>
<th>Limits</th>
<th>Test method</th>
<th>Test frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Physical test</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Density test for recycled water</td>
<td>≤ 1030 kg/m³</td>
<td>Note 1 BS EN 196-3:1995</td>
<td>At least once per day</td>
</tr>
<tr>
<td>(b) Initial setting time of cement with recycled water</td>
<td>From 1:00 earlier to 1:30 later</td>
<td></td>
<td>Once every 3 months for the first year and thereafter at half-yearly intervals</td>
</tr>
<tr>
<td><strong>Chemical test for recycled water</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) Chloride content (as Cl(^{-}))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- prestressed concrete steam-cured structural concrete</td>
<td>500 ppm</td>
<td>APHA 4500-C1-B, 18th Edition (1992)</td>
<td>(i) Once per week for the first 2 months</td>
</tr>
<tr>
<td>- concrete with reinforcement or other embedded metal</td>
<td>1,000 ppm</td>
<td>APHA 4500-Cl-B, 18th Edition (1992)</td>
<td>(ii) Once per month for the next 12 months thereafter</td>
</tr>
<tr>
<td>(b) Sulphate content (as SO(_4))</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3,000 ppm</td>
<td>APHA 4500-SO42-C, 18th Edition (1992)</td>
<td>(iii) In case of a weekly or monthly test indicates that the limits are exceeded, the water shall immediately be suspended for use in concrete mixing until two sets of consecutive test results taken from the same source are satisfactory. In such case, the testing frequency shall be maintained at or reverted back to once per week until two sets of consecutive test results are satisfactory.</td>
</tr>
<tr>
<td>(c) Acid-soluble alkali content</td>
<td>600 ppm</td>
<td>BS EN 1008:2002</td>
<td>(iv) The testing frequency shall be subject to review after the 12-month period for the monthly test</td>
</tr>
</tbody>
</table>

**Notes:**
1. Test method to be proposed by the Contractor for the acceptance of the Engineer.
2. Laboratories accredited by HOKLAS for the relevant tests shall be used, if available, in which case results shall be issued on HOKLAS endorsed test reports.

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**TESTING: CONCRETE - GENERAL REQUIREMENTS**

**Batch: concrete**

16.52 A batch of concrete is any quantity of concrete produced in one cycle of operations of a batch mixer, or conveyed ready-mixed in a delivery vehicle, or discharged during one minute from a continuous mixer.

**Reduction of testing frequency**

16.53 The number of tests for workability or compressive strength of standard mix concrete may be reduced if in the opinion of the Engineer the standard of quality control is satisfactory.
TESTING: CONCRETE - WORKABILITY

**Samples: workability of concrete**

16.54 (1) One sample of concrete shall be provided from each batch of concrete to determine the workability of the concrete.

(2) The size of each sample and the method of sampling shall be in accordance with CS1.

(3) The first 0.3 cu. m. concrete discharged from the truck before taking concrete sample for slump test can be used in the Works after the slump value is accepted by the Engineer as in Clause 16.56.

**Testing: workability of concrete**

16.55 (1) Each sample of concrete taken as stated in Clause 16.54 shall be divided into two specimens. Each specimen shall be tested to determine the workability of the concrete in accordance with CS1. Selection of the testing method is given in the table below:

<table>
<thead>
<tr>
<th>Normal Workability (slump value from 10 mm to 200 mm)</th>
<th>High Workability (flow value from 340 mm to 600 mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slump Test</td>
<td>Flow Table Test (See Note below)</td>
</tr>
</tbody>
</table>

Note: For concrete with a flow value greater than 600mm, the Engineer shall specify the workability testing method.

(2) The average of the two workability values shall be calculated and referred to as the average slump value or average flow value.

**Compliance criteria: workability of concrete**

16.56 (1) The average slump value of the two specimens taken from one sample of standard mix concrete shall be within the appropriate range stated in Table 16.3.

(2) The average slump value of the two specimens taken from one sample of designed mix concrete shall be within 25 mm or 33% of the approved slump value, whichever is the greater.

(3) The average flow value of the two specimens taken from one sample of designed mix concrete shall be within +/- 50mm of the approved flow value.

**Non-compliance: workability of concrete**

16.57 A batch of concrete shall be considered as not complying with the specified requirements for workability if the result of any test for workability, carried out on a sample taken from the batch, does not comply with the specified requirements for workability. Concrete that failed to comply with the specified requirements for workability shall not be placed in the permanent works.
TESTING: CONCRETE - COMPRESSION STRENGTH

Samples: compressive strength of concrete 16.58

(1) For each concrete mix, one sample of concrete shall be provided from each amount of concrete as stated in Table 16.9 or from the amount of concrete produced each day, whichever is less.

(2) If the Contractor requests, or if the Engineer instructs, that the concrete be tested for compressive strength at ages other than 28 days, additional samples shall be provided. The number of additional samples shall be as stated in Clause 16.58(1).

(3) The size of each sample and the method of sampling shall be in accordance with CS1. If a superplasticising admixture is included in the concrete mix, the samples shall be taken after the superplasticiser is added and after the concrete is remixed.

Table 16.9: Rate of sampling of concrete

<table>
<thead>
<tr>
<th>Type of structure</th>
<th>Amount of concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masts</td>
<td>10 m³ or 10 batches, whichever is less</td>
</tr>
<tr>
<td>Cantilevers 3 m or more in length</td>
<td></td>
</tr>
<tr>
<td>Columns</td>
<td></td>
</tr>
<tr>
<td>Shear walls</td>
<td></td>
</tr>
<tr>
<td>Prestressed elements</td>
<td></td>
</tr>
<tr>
<td>Other critical elements</td>
<td></td>
</tr>
<tr>
<td>Solid rafts</td>
<td>100 m³ or 100 batches, whichever is less</td>
</tr>
<tr>
<td>Pile caps</td>
<td></td>
</tr>
<tr>
<td>Mass concrete</td>
<td></td>
</tr>
<tr>
<td>Other types</td>
<td>25 m³ or 25 batches, whichever is less</td>
</tr>
</tbody>
</table>

Testing: compressive strength of concrete 16.59

(1) Two test cubes shall be made from each sample of concrete taken as stated in Clause 16.58. Each pair of test cubes shall be tested to determine the compressive strength at 28 days.

(2) The method of making test cubes shall be in accordance with CS1.

(3) The method of storing test cubes shall be in accordance with CS1. Test cubes which are cured on the Site shall be delivered to the testing laboratory at least 48 hours before the tests are due to be carried out.

(4) The method of testing shall be in accordance with CS1.

(5) For the purpose of assessing compliance of designed mix concrete as stated in Clauses 16.61 and 16.62, the average of the two compressive strengths of the pair of test cubes shall be calculated and referred to as the test result.
The size of the test cube shall be 100 mm for concrete with the maximum aggregate size not exceeding 20 mm and shall be 150 mm with the maximum aggregate size exceeding 20 mm.

Non-compliance: compressive strength of standard mix concrete

If the result of any test for compressive strength at 28 days of standard mix concrete is less than the grade strength, the Engineer may instruct that tests as stated in Clauses 16.63 to 16.66 are carried out on concrete cores or on samples taken from the hardened concrete.

Compliance criteria: compressive strength of designed mix concrete

The results of tests for compressive strength at 28 days of designed mix concrete shall comply with the following requirements:

(a) Each test result shall not be less than the grade strength by more than the appropriate amount stated in Column A of Table 16.10, and,

(b) The average of any four consecutive test results, or the average of the first two or first three test results if less than four test results are available, shall exceed the grade strength by at least the appropriate amount stated in Column B of Table 16.10.

Table 16.10: Compliance criteria for compressive strength of designed mix concrete

<table>
<thead>
<tr>
<th>Grade strength (MPa)</th>
<th>Compliance criteria</th>
<th>Column A</th>
<th>Column B</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Maximum amount by which each test result may be below the grade strength (MPa)</td>
<td>Minimum amount by which the average of any four consecutive test results shall be above the grade strength (MPa)</td>
<td></td>
</tr>
<tr>
<td>100 mm cubes</td>
<td>150 mm cubes</td>
<td>100 mm cubes</td>
<td>150 mm cubes</td>
</tr>
<tr>
<td>20 or greater</td>
<td>C1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>C2</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>below 20</td>
<td>C3</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

If there is a period exceeding 14 days between any two consecutive test results in any group of four consecutive test results and if agreed by the Engineer, the test results immediately before and immediately after the period may be treated separately for the purpose of Clause 16.61(1)(b).

If the difference between the compressive strengths of two test cubes made from one sample of designed mix concrete exceeds 15% of the test result:

(a) The higher of the compressive strengths of the two test cubes shall be used to assess compliance as stated in Clause 16.61(1)(a), and
(b) The test result for that sample shall not be used to assess compliance as stated in Clause 16.61(1)(b) and shall not be used to calculate the standard deviation.

(4) For designed mix concrete with grade strength of less than 20 MPa, compliance criteria C3 shall apply.

(5) For designed mix concrete with a grade strength of 20 MPa or greater, until 40 test results are available either:

(a) Compliance criteria C1 shall apply, or

(b) If in the opinion of the Engineer there is sufficient evidence that the standard of quality control using similar materials and plant is such that the standard deviation for at least 40 test results will not exceed 5.5 MPa for 100 mm test cubes or 5 MPa for 150 mm test cubes, compliance criteria C2 shall apply.

(6) For designed mix concrete with a grade strength of 20 MPa or greater, the standard deviation of test results shall be calculated after every test result for each designed mix using the last 40 test results judged by the same compliance criteria. The acceptance criteria shall depend on the calculated standard deviation as follows:

(a) For 100 mm test cubes, if the standard deviation does not exceed 5.5 MPa, compliance criteria C2 shall apply to subsequent test results. If the standard deviation exceeds 5.5 MPa and does not exceed 8.5 MPa, compliance criteria C1 shall apply to subsequent test results.

(b) For 150 mm test cubes, if the standard deviation does not exceed 5 MPa, compliance criteria C2 shall apply to subsequent test results. If the standard deviation exceeds 5 MPa and does not exceed 8 MPa, compliance criteria C1 shall apply to subsequent test results.

(c) If the standard deviation exceeds 8.5 MPa for 100 mm test cubes or 8.0 MPa for 150 mm test cubes, no further concrete shall be placed in the permanent works until an investigation of the materials, mix design, methods of production, sampling and testing has been carried out and measures have been taken which in the opinion of the Engineer will result in restoring a satisfactory standard of quality control.

(7) If the compliance criteria are changed from C1 to C2 or from C2 to C1, the new compliance criteria shall apply from the 35th day after making the last pair of test cubes in the set of 40 on which the decision to change was based. For the purpose of Clause 16.61(1)(b), test results immediately before and immediately after the change shall be treated separately.

Non-compliance: compressive strength of designed mix concrete

16.62 (1) A batch of designed mix concrete shall be considered as not complying with the specified requirements for compressive strength if the test result for the pair of test cubes made from a sample taken from the batch does not comply with the requirements stated in Clause 16.61(1)(a).
(2) The batches of designed mix concrete from which the first and last samples in any group of four consecutive test results were taken and all intervening batches shall be considered as not complying with the specified requirements for compressive strength if the group of four consecutive test results does not comply with the requirements stated in Clause 16.61(1)(b).

(3) If designed mix concrete is considered as not complying with the specified requirements for compressive strength, the Engineer may instruct that tests as stated in Clauses 16.63 to 16.66 are carried out on concrete cores or on samples taken from the hardened concrete.

**TESTING: HARDENED CONCRETE**

### Samples: hardened concrete and concrete cores

16.63 (1) The number of samples, including cores, of hardened concrete to be provided for testing shall be as stated in the Contract or, if testing is to be carried out as a result of the concrete not complying with the specified requirements, shall be as instructed by the Engineer. In the latter case, all the concrete being investigated shall be divided as instructed by the Engineer into separate test locations. The number of samples taken from each location shall be as instructed by the Engineer and the quality of concrete at each location shall be assessed separately. The positions from which the samples are taken shall be as instructed by the Engineer.

(2) The size of samples and the method of sampling shall be in accordance with CS1.

### Testing: concrete cores

16.64 (1) Each concrete core shall be inspected for evidence of segregation of the constituents and for the presence of voids. Specimens selected from each core shall be tested to determine the compressive strength.

(2) The method of preparing and inspecting concrete cores and of testing the cores to determine the compressive strength shall be in accordance with CS1. Concrete cores shall not be tested for compressive strength until the concrete has reached an age of 28 days.

### Compliance criteria: concrete cores

16.65 (1) The concrete core shall be considered as non-compliant if it exhibits honeycombing which means interconnected voids arising from, for example, inadequate compaction or lack of mortar.

(2) The results of tests for compressive strength of concrete cores shall be interpreted in accordance with BS 6089. Adjustments to the measured strength in respect of the age of the core when tested shall not be made unless permitted by the Engineer. The estimated in-situ cube strength of each core specimen shall be calculated in accordance with CS1. For any set of cores representing a test location, the average estimated equivalent cube strength shall be at least 85% of the specified grade strength, and each individual estimated equivalent cube strength shall be at least 75% of the specified grade strength.

### Analysis of hardened concrete

16.66 (1) Each sample of hardened concrete shall be tested to determine the properties or the composition of the concrete as stated in the Contract or, if testing is to be carried out as a result of the concrete not complying with the specified requirements, shall be tested as instructed by the Engineer.
(2) Tests on hardened concrete shall be carried out within 14 days of the Engineer's instruction for the test.

(3) The method of testing shall be in accordance with CS1.

TESTING: PRECAST UNITS

**Batch: precast units**

16.67 A batch of precast units is any quantity of precast units, including prestressed units, of the same type and size, of the same concrete mix, manufactured in the same place, covered by the same certificates and delivered to the Site at any one time.

**Samples: precast units**

16.68 The number of precast units to be provided for testing from each batch shall be as stated in the Contract.

**Testing: precast units**

16.69 (1) Load tests shall be carried out to determine the deflection and recovery of each precast unit, including prestressed units, provided for testing and to determine the resistance to cracking of each prestressed unit provided for testing.

(2) Load tests shall be carried out in accordance with a procedure agreed by the Engineer. The age at which the units are to be tested, the test load, the points at which the loads are to be applied and the points at which the unit is to be supported shall be as stated in the Contract.

(3) The method of testing shall be as stated in Appendix 16.2.

(4) Post-tensioned units shall not be tested until at least 7 days after the ducts have been grouted.

**Compliance criteria: precast units**

16.70 The results of load tests on precast units shall comply with the requirements stated in the Contract.
PART 2: JOINTS IN CONCRETE

GENERAL

General requirements 16.71 The works and materials specified in Clauses 16.72 and 16.73 shall comply with the sections stated, unless otherwise stated in this Section.

Joints in concrete carriageways 16.72 Joints in concrete carriageways shall comply with Section 10.

Construction joints 16.73 Construction joints in concrete shall comply with Section 16.

MATERIALS

Materials for joints in water retaining structures and water tight structures 16.74 (1) Materials for joints in water retaining structures and water tight structures for sewage and effluent treatment shall be resistant to aerobic and anaerobic microbiological attack and resistant to attack by petrol, diesel oil, dilute acids and alkalis.

(2) Materials for joints in water retaining structures for potable and fresh water shall comply with the requirements of BS 6920.

Joint filler 16.75 Joint filler shall be of a proprietary type approved by the Engineer and shall be a firm, compressible, single-thickness, non-rotting filler. Joint filler for joints in water retaining structures and watertight structures shall be non-absorbent.

Bitumen emulsion 16.76 Bitumen emulsion for joints in water retaining structures and watertight structures shall comply with BS 3416. Bitumen emulsion for surfaces against which potable or fresh water will be stored or conveyed shall comply with BS 3416, type II.

Joint sealant 16.77 (1) Joint sealant shall be a grade suited to the climatic conditions of Hong Kong and shall perform effectively over a temperature range of 0°C to 60°C. Joint sealant for exposed joints shall be grey.

(2) Joint sealant other than cold-applied bitumen rubber sealant shall be:

(a) A gun grade for horizontal joints 15 mm wide or less and for vertical and inclined joints,

(b) A pouring grade for horizontal joints wider than 15 mm.

(3) Polysulphide-based sealant shall be a cold-applied two-part sealant complying with BS 4254. Polysulphide-based sealant for expansion joints in water retaining structures and watertight structures shall have a transverse butt-joint movement range of at least 20%.

(4) Polyurethane-based sealant shall be a cold-applied two-part sealant complying with the performance requirements of BS 4254.

(5) Hot-applied bitumen rubber sealant shall comply with BS 2499, type N1.
(6) Cold-applied bitumen rubber sealant shall be of a proprietary type approved by the Engineer.

(7) Joint sealant for joints in water retaining structures and water tight structures shall be as stated in Table 16.11.

(8) Primers and caulking material for use with joint sealant shall be of a proprietary type recommended by the joint sealant manufacturer and approved by the Engineer.

(9) Different types of joint sealant and primers that will be in contact shall be compatible.

Table 16.11: Joint sealant for water retaining structures and water tight structures

<table>
<thead>
<tr>
<th>Structure for retaining/excluding</th>
<th>Type of joint</th>
<th>Type of joint sealant</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewage</td>
<td>All joints</td>
<td>Polyurethane-based</td>
</tr>
<tr>
<td>Other than sewage</td>
<td>Expansion joints</td>
<td>Polysulphide-based or polyurethane-based</td>
</tr>
<tr>
<td></td>
<td>Horizontal joints other than expansion joints</td>
<td>Hot-applied bitumen rubber, polysulphide-based or polyurethane-based</td>
</tr>
<tr>
<td></td>
<td>Vertical and inclined joints other than expansion joints</td>
<td>Polysulphide-based, polyurethane-based or cold-applied bitumen rubber</td>
</tr>
</tbody>
</table>

**Bond breaker tape** 16.78 Bond breaker tape shall be of a proprietary type recommended by the joint sealant manufacturer and approved by the Engineer. The tape shall be a polyethylene film with adhesive applied on one side and shall be the full width of the groove.

**Bearing strip for sliding joints** 16.79 Bearing strip for sliding joints shall consist of two plastic strips of a proprietary type approved by the Engineer. The strips shall be resistant to all weather conditions and to chemicals to which the structure will be subjected without impairing the reaction, durability or function of the strips. The strips shall be of a type that will not require maintenance after installation. The strips shall be capable of withstanding a vertical load of at least 300 kN/m² and shall have a maximum coefficient of friction of 0.3 under a constant shearing force.

**Waterstops** 16.80 Waterstops, including intersections, reducers and junctions, shall be of a proprietary type approved by the Engineer. Waterstops shall be natural or synthetic rubber or extruded polyvinyl chloride and shall have the properties stated in Table 16.12.
Table 16.12: Properties of waterstops

<table>
<thead>
<tr>
<th>Property</th>
<th>Rubber waterstops</th>
<th>PVC waterstops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>1100 kg/m³ (± 5%)</td>
<td>1300 kg/m³ (± 5%)</td>
</tr>
<tr>
<td>Hardness</td>
<td>60 - 70 IRHD</td>
<td>70 – 90 IRHD</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>≥ 20 N/mm²</td>
<td>≥ 13 N/mm²</td>
</tr>
<tr>
<td>Elongation at break point</td>
<td>≥ 450%</td>
<td>≥ 285%</td>
</tr>
<tr>
<td>Water absorption</td>
<td>≤ 5% by mass after 48 hours immersion</td>
<td>≤ 0.15% by mass after 24 hours immersion</td>
</tr>
<tr>
<td>Softness number</td>
<td>-</td>
<td>42 - 52</td>
</tr>
</tbody>
</table>

**SUBMISSIONS**

Particulars of materials for joints

16.81 (1) The following particulars of the proposed materials for joints shall be submitted to the Engineer:

(a) Manufacturer’s literature and a certificate for joint filler showing the manufacturer's name, the date and place of manufacture and showing that the joint filler complies with the requirements stated in the Contract and including results of tests for:
   - Disintegration and shrinkage
   - Recovery value and reduction in mass
   - Extrusion,

(b) Manufacturer’s literature and a certificate for bitumen emulsion showing the manufacturer's name, the date and place of manufacture and showing that the bitumen emulsion complies with the requirements stated in the Contract,

(c) Manufacturer’s literature for joint sealant, including details of the method and time required for mixing the different components, and a certificate showing the manufacturer's name, the date and place of manufacture and showing that the sealant complies with the requirements stated in the Contract and including results of tests as appropriate for:
   - Rheological properties
   - Plastic deformation
   - Adhesion and tensile modulus
   - Application life
- Adhesion in peel
- Loss of mass after heat ageing
- Staining
- Transverse butt joint movement range
- Extension
- Flow
- Penetration
- Degradation,

(d) Manufacturer’s literature and a certificate for bearing strip for sliding joints showing the manufacturer's name, the date and place of manufacture and showing that the strips comply with the requirements stated in the Contract and including results of tests for:
- Vertical load
- Coefficient of friction,

(e) Manufacturer’s literature for waterstops, including details of intersections, reducers and junctions, and a certificate showing the manufacturer's name, the date and place of manufacture and showing that the waterstops comply with the requirements stated in the Contract and including results of tests for:
- Density
- Hardness
- Tensile strength
- Elongation at break point
- Water absorption
- Softness number of PVC waterstops, and

(f) Particulars of primers and caulking material for joint sealant and of bond breaker tape.

(2) The particulars, including certificates, shall be submitted to the Engineer at least 14 days before the first delivery of the material to the Site. Certificates shall be submitted for each batch of the material delivered to the Site.

**Samples of materials**

Samples of the following proposed materials shall be submitted to the Engineer at the same time as particulars of the material are submitted:

(a) Joint filler,

(b) Bond breaker tape,

(c) Bearing strip for sliding joints, and

(d) Waterstops, including intersections, reducers and junctions.
STORAGE OF MATERIALS

**Storage of materials for joints** 16.83

1. Bitumen emulsion, joint sealant and primer for joint sealant shall be stored in sealed containers marked to identify the contents and protected from exposure to conditions which may affect the material. The materials shall be stored in accordance with the manufacturers' recommendations and shall not be used after the recommended shelf life has been exceeded.

2. Joint filler, bond breaker tape and waterstops shall be stored in accordance with the manufacturers' recommendations in a dry weatherproof store with a raised floor. Absorbent joint filler shall be stored in sealed plastic bags and shall not be exposed to moisture or air.

3. Bearing strip for sliding joints supplied in rolls of 5 m length or less shall be unrolled immediately after delivery and shall be stored flat at full length on an even surface. Bearing strip supplied in rolls of more than 5 m length may be left in the original packing. Bearing strip shall be stored in accordance with the manufacturer’s recommendations and shall be protected from mechanical damage and creasing. The two layers of strip shall be kept free from deleterious material.

**FORMING JOINTS**

**Forming joints** 16.84

1. Materials for joints shall be used in accordance with the manufacturers’ recommendations or as otherwise stated in the Contract.

2. Joint filler shall be cut to size before fixing and shall be securely fixed in position to the existing concrete surface before concreting. There shall be no gaps between the joint filler and formation.

3. Waterstops shall be securely fixed in position to formwork in such a manner that compaction of the concrete will not be affected. In-situ joints in waterstops shall be made using methods and equipment recommended by the manufacturer. Exposed waterstops shall be protected from exposure to conditions that may affect the waterstop and shall be kept free from rust, hydrocarbons and other deleterious material.

4. Joints shall be formed in straight lines perpendicular to the surface of the concrete unless otherwise stated in Contract.

**Forming grooves** 16.85

1. Grooves for joint sealant shall be straight and shall be perpendicular to the surface of the concrete. The bottom of the groove shall be flat and shall be parallel to the surface of the concrete.

2. Grooves shall be formed by using timber or other approved formers and shall not be formed by cutting back or raking out the joint filler. The grooves shall be located over the joint filler such that the upper surface of the joint filler is entirely contained in the groove.

**Protection of grooves** 16.86

Before permanent sealing, grooves for joint sealant shall be protected from contamination by a temporary sealing strip or cover or by other methods agreed by the Engineer.
Sealing joints

16.36

16.87  (1) The permanent sealing of joints shall be carried out at least 7 days after concreting unless otherwise permitted by the Engineer.

(2) Immediately before permanent sealing, timber formers, temporary seals, dirt and loose material shall be removed from the groove and the sides of the groove shall be cleaned and roughened by water jetting, sand blasting or by other methods agreed by the Engineer.

(3) Caulking material shall be firmly packed in the bottom of the groove if the joint sealant is not required to extend to the bottom of the groove.

(4) Bond breaker tape shall be fixed continuously and evenly along the bottom of the groove for the full width and length of the groove.

(5) Concrete surfaces within 75 mm of the edges of the joint shall be masked with tape before the primer is applied and until the sealing of the joint is complete.

(6) Primer for the joint sealant shall be applied to the sides of the groove in accordance with the manufacturer’s recommendations.

(7) Joint sealant shall be applied between the minimum and maximum drying times of the primer recommended by the manufacturer. The components of the sealant shall be thoroughly mixed in accordance with the manufacturer's recommendations using a power operated paddle mixer for sufficient time to produce a homogeneous mass without entrapped air. The sealant shall be dispensed into the groove as soon as practicable after mixing and within the time recommended by the manufacturer.

(8) The groove shall be clean and dry at the time of applying the primer and joint sealant.

(9) Excess joint sealant shall be removed by using a purpose made finishing tool such that the finished surface of the sealant is between 4 mm and 6 mm below the face of the concrete.

TOLERANCES

Tolerances: joints

16.88  (1) The best-fit straight line of straight joints shall be within 25 mm of the specified line. The line of straight joints shall be within 10 mm of the best-fit straight line.

(2) The best-fit curved line of curved joints shall be as agreed by the Engineer and shall be within 25 mm of the specified line. The line of curved joints shall be within 10 mm of the best-fit curved line.

(3) Joints shall be continuous across intersections of joints to within 5 mm of the best fit straight lines or best fit curved lines of each joint.

(4) The depth of grooves for joint sealant shall be within 3 mm of the specified depth.
Batch: joint filler, joint sealant, waterstops 16.89
A batch of joint filler, joint sealant or waterstop is any quantity of joint filler, joint sealant or waterstop of the same type, manufactured by the same manufacturer, covered by the same certificates and delivered to the Site at any one time.

Samples: joint filler, joint sealant, waterstops 16.90
(1) One sample of each type of joint filler, joint sealant or waterstop shall be provided at the same time as particulars of the material are submitted to the Engineer. Unless otherwise permitted by the Engineer, one sample of each type of material shall be provided from each batch of the material delivered to the Site. Unless otherwise permitted by the Engineer, one sample of mixed joint sealant shall be provided on each day that joints are sealed.

(2) The size of each sample of joint filler shall be sufficient to permit all tests stated in Appendix 16.3 to be carried out.

(3) Samples of unmixed joint sealant and primers for joint sealant shall be taken from sealed containers delivered to the Site. Samples of mixed joint sealant shall be taken immediately before the sealant is applied to the joint. The method of sampling shall be as stated in BS 2499, Appendix A. The size of each sample shall be as follows:

(a) Unmixed joint sealant : 1 kg
(b) Mixed joint sealant : 1.5 kg
(c) Primer for joint sealant : 1 L.

(4) The size of each sample of waterstop shall be 1 m.

Testing: joint filler, joint sealant, waterstops 16.91
(1) If required by the Engineer, samples of joint filler shall be tested to determine the disintegration and shrinkage, the recovery value and reduction in mass and the extrusion. The method of testing shall be in accordance with Appendix 16.3.

(2) If required by the Engineer, samples of joint sealant shall be tested to determine the properties stated in Table 16.13. The method of testing shall be as stated in Table 16.13.

(3) If required by the Engineer, samples of waterstop shall be tested to determine the properties stated in Table 16.14. The method of testing shall be as stated in Table 16.14.
### Table 16.13: Testing joint sealant

<table>
<thead>
<tr>
<th>Type of joint sealant</th>
<th>Properties to be tested</th>
<th>Method of testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polysulphide-based sealant</td>
<td>Rheological properties</td>
<td>BS 4254</td>
</tr>
<tr>
<td>Polyurethane-based sealant</td>
<td>Plastic deformation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adhesion and tensile modulus</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Application life</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Adhesion in peel</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Loss of mass after heat ageing</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Staining</td>
<td></td>
</tr>
<tr>
<td>Hot-applied bitumen rubber sealant</td>
<td>Extension</td>
<td>BS 2499</td>
</tr>
<tr>
<td></td>
<td>Flow</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Penetration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Degradation</td>
<td></td>
</tr>
</tbody>
</table>

### Table 16.14: Testing waterstops

<table>
<thead>
<tr>
<th>Property</th>
<th>Method of testing</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rubber waterstops</td>
</tr>
<tr>
<td>Density</td>
<td>BS 903: Part A1</td>
</tr>
<tr>
<td>Hardness</td>
<td>BS 903: Part A26</td>
</tr>
<tr>
<td>Tensile strength</td>
<td>BS 903: Part A2 and BS 903: Part A5</td>
</tr>
<tr>
<td>Elongation at break point</td>
<td>BS 903: Part A2 and BS 903: Part A5</td>
</tr>
<tr>
<td>Water absorption</td>
<td>BS 903: Part A18</td>
</tr>
<tr>
<td>Softness number</td>
<td>-</td>
</tr>
</tbody>
</table>

**Compliance criteria: joint filler**

16.92 The results of tests on joint filler shall comply with the following requirements:

(a) None of the three specimens in the weathering test shall show any sign of disintegration or shrinkage.

(b) Each of the four specimens in the compression and recovery test shall have a recovery value of at least 70%, and the reduction in mass of each of the two new specimens shall not exceed 1%.

(c) The extrusion of the free edge of the specimen shall not exceed 6 mm as determined by the extrusion test.
APPENDIX 16.1

DETERMINATION OF THE EFFICIENCY INDEX OF CURING COMPOUNDS

Scope  16.1.1 This method covers the determination of the efficiency index of membrane forming curing compounds for concrete.

Materials  16.1.2 The following materials are required:

(a) Portland cement complying with BS EN 197-1, specially selected for testing admixtures and identified as ‘CAA/BS 5075: Part 1 Reference Portland Cement’. The cement shall be stored in an airtight container.

(b) Oven-dry natural sand with a rounded particle shape complying with BS 882 and with the grading stated in Table 16.1.1.

(c) Petroleum jelly, mineral oil or a proprietary release agent.

Table 16.1.1: Grading of sand

<table>
<thead>
<tr>
<th>BS test sieve</th>
<th>Percentage by mass passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.18 mm</td>
<td>100</td>
</tr>
<tr>
<td>600 µm</td>
<td>90 - 100</td>
</tr>
<tr>
<td>300 µm</td>
<td>12 - 40</td>
</tr>
<tr>
<td>150 µm</td>
<td>0 - 6</td>
</tr>
</tbody>
</table>

Apparatus  16.1.3 The following apparatus is required:

(a) Moulds constructed of corrosion resistant metal. The moulds shall be watertight, tapered and constructed so as to prevent distortion and shall have the following dimensions:

- Internal size (top): :150 mm (0mm to +5 mm) x 300 mm (0mm to +5 mm)
- Internal size (bottom) : 145 mm (0mm to +5 mm) x 295 mm (0mm to +5 mm)
- Internal depth : 50 mm ± 2 mm
- Side and end slope : 5% ± 1%
- Top flange width : at least 12 mm.

(b) A balance readable and accurate to 0.1 g.
(c) A cabinet complying with BS 2648 capable of storing specimens at a temperature of 38°C ± 1°C and at a relative humidity of 35% ± 5%. The cabinet shall have three perforated or mesh shelves each capable of supporting two specimens during test so as to ensure a clear space of at least 40 mm on all sides of individual specimens. The cabinet shall be equipped to circulate air over the specimens at an approximate rate of 0.5 m/s.

(d) Spray equipment, such as the Wagner model W320 electric spray gun, designed to permit the curing compound to be aspirated and applied evenly to the specimen.

(e) An electrically driven mixer complying with Clause 8.3 of BS4551 and having a nominal capacity of 12 kg.

(f) A vibrating table or a vibrating hammer with a 40 mm square foot or a compacting bar made of non-absorbent material, approximately 200 mm long and with a 40 mm square foot.

(g) A metal screed, 148 mm long, of L-shaped Section 50 mm x 25 mm with the shorter side having a sharpened leading edge. The screed shall be supported across the top of the mould by a 200 mm long rigid member that can slide on the flanges of the mould while holding the screed horizontal. The height of the screed shall be adjustable to give a uniformly flat surface finish to the mortar 7 mm ± 1 mm below the top of the mould.

(h) A metal tray with sides at least 3 mm high and an area equal to the surface area of the specimen.

(i) A hydrometer complying with BS 718.

(j) A float, 250 mm x 140 mm ± 5 mm.

(k) A medium soft 50 mm paint brush.

**Procedure:**

**preparation of specimens**

16.1.4 The procedure for preparation of the specimens shall be as follows:

(a) Three pairs of specimens shall be prepared, each pair comprising one test specimen and one control specimen.

(b) Mixing shall be carried out in a room having a temperature of 27°C ± 3°C. The materials shall be brought to room temperature before mixing. A mortar mix shall be prepared comprising one part by mass of cement, three parts by mass of sand and 0.44 parts by mass of water.

(c) The sand and cement shall be placed in the mixer and mixed for 1 minute. The water shall be added and mixing continued for a further 4 minutes.

(d) The two moulds shall be cleaned, lightly coated with the petroleum jelly, mineral oil or release agent and weighed to the nearest 0.1 g (m1).

(e) The specimens shall be prepared 20 minutes after completion of mixing and shall be cast in pairs.
(f) A layer of mortar approximately 25 mm deep shall be placed in each mould and tamped 50 times with the compacting bar. A second layer of mortar, sufficient to overfill the moulds slightly, shall be placed in each mould and tamped 50 times with the compacting bar. Indentations formed by tamping shall be filled and the surface shall be levelled by vigorous compaction by manual methods. Alternatively, each layer shall be compacted by using the vibrating table or vibrating hammer and levelled using the float.

(g) A uniform surface, free from undulations and surface defects, shall be produced using the minimum number of passes of the metal screed working along the length of the mould in both directions. The finished surface shall be 7 mm ± 1 mm below the top of the mould.

(h) The surface shall be brushed lightly with the paint-brush to give an even texture.

(i) The moulds and specimens shall each be weighed to the nearest 0.1 g (m2) immediately before the curing compound is applied.

**Procedure: determination of efficiency index**

16.1.5 The procedure for determination of the efficiency index shall be as follows:

(a) A sample of the curing compound shall be taken by the method for sampling admixtures in accordance with BS 5075: Part 1, Appendix A.

(b) The sample shall be agitated thoroughly and the relative density determined at room temperature with the hydrometer. The mass required to give the coverage rate stated in Clause 16.1.5(c) shall be calculated from the relative density. The mass of the curing compound applied shall be within ± 0.5 g of that required to give the specified coverage rate.

(c) The curing compound shall be applied at the coverage rate recommended by the manufacturer, or at a rate of 0.2 L/m2 ± 0.01 L/m2 if no rate is recommended.

(d) The curing compound shall be applied to the test specimen one hour after the specimen has been prepared, using the spray equipment or in accordance with the manufacturer's recommendations. The curing compound shall be shaken well before and during application. The spray gun shall be held so that the nozzle is as near vertical as possible and at a height that will result in uniform application and minimum overspray. The specimen shall be coated uniformly by applying several layers over the whole surface until the specified coverage is reached, checked by repeated weighing. Over spray shall be wiped from the exposed faces and edges of the mould. The whole application procedure shall be completed in not more than 2 minutes.

(e) The test specimen and the control specimen shall each be weighed to the nearest gram (m3) and placed immediately on the lowest shelf of the cabinet. After the second pair of specimens has been prepared and weighed, the first pair shall be moved up one shelf and the second pair placed on the lowest shelf. After the third pair of specimens has been prepared and weighed, the first two pairs shall be moved up one shelf and the third pair placed on the lowest shelf.
(f) The total time for making the specimens, coating the test specimen and placing the pair in the cabinet shall not exceed 2 hours.

(g) The specimens shall be kept in the cabinet for 72 hours ± 15 minutes after application of the curing compound. Each specimen shall be weighed to the nearest 0.1 g at 24 hours ± 15 minutes and 48 hours ± 15 minutes. Each specimen shall be weighed to the nearest 0.1 g (m₄ and m₅) at 72 hours ± 15 minutes.

(h) The metal tray shall be weighed to the nearest 0.1 g (m₆) and coated with the same quantity ± 0.5 g of curing compound used on the test specimen. The coated tray shall be weighed to the nearest 0.1 g (m₇) and placed in the cabinet for 72 hours ± 15 minutes after application of the curing compound. The tray shall be removed from the cabinet and weighed to the nearest 0.1 g (m₈).

Calculation

16.1.6 (1) The proportion of solvent lost (V) by the curing compound during the test period shall be calculated from the equation:

\[ V = \frac{(m₇ - m₈)}{(m₇ - m₆)} \]

where:
- \( m₆ \) is the mass of the tray (g)
- \( m₇ \) is the mass of the tray after coating (g)
- \( m₈ \) is the mass of the tray after 72 hours in the cabinet (g)

(2) The loss of water from the test specimen (\( Wₜ \)) and the loss of water from the control specimen (\( W_c \)) shall be calculated for each pair of specimens from the equation:

\[ Wₜ = \frac{(m₃ - m₄) - V(m₃ - m₂)}{(m₂ - m₁)} \times 100\% \]

\[ W_c = \frac{(m₂ - m₅)}{(m₂ - m₁)} \times 100\% \]

where:
- \( m₁ \) is the mass of the mould (g)
- \( m₂ \) is the mass of the mould and test or control specimen as appropriate (g)
- \( m₃ \) is the mass of the mould and test specimen after coating (g)
- \( m₄ \) is the mass of the mould and test specimen after 72 hours in the cabinet (g)
- $m_5$ is the mass of the mould and control specimen after 72 hours in the cabinet (g)

(3) The efficiently index ($E'$) of the curing compound shall be calculated for each test specimen from the equation:

$$E' = \frac{(W_c - W_t)}{W_c} \times 100\%$$

The efficiency index ($E$) of the curing compound shall be calculated as the average of $E'$ for the three test specimens.

**Reporting of results** 16.1.7 The following shall be reported:

(a) Details of the sample of curing compound including identification, source, size, date received and age at test.

(b) The method of compacting the mortar.

(c) The method of applying the curing compound and the type of spray gun used.

(d) The rate of application of the curing compound to the nearest 0.01 L/m$^2$.

(e) The duration of the test.

(f) The efficiency index of the curing compound to the nearest 0.1%.

(g) That the test method used was in accordance with this Specification.
APPENDIX 16.2

DETERMINATION OF THE DEFLECTION, RECOVERY AND RESISTANCE TO CRACKING OF PRECAST UNITS

Scope

16.2.1 This method covers the determination of the deflection and recovery of precast units, including prestressed units, and the resistance to cracking of prestressed units by means of a load test.

Equipment

16.2.2 The following equipment is required:

(a) Rigid supports.
(b) Test loads.
(c) Equipment for measuring the loads applied, readable and accurate to 2% of the specified test load.
(d) Equipment for measuring the deflection and recovery, readable and accurate to 0.5 mm.

Procedure

16.2.3 The procedure shall be as follows:

(a) The precast unit shall be supported at the specified points of support.
(b) The upward deflection at mid-span due to the prestressing force in a prestressed unit and the deflection at mid-span due to the self-weight of a non-prestressed unit shall be measured.
(c) The specified test load shall be applied at the specified loading points in not less than ten approximately equal increments.
(d) The specified test load shall be maintained for 5 minutes and removed in not less than five approximately equal decrements.
(e) The deflection at mid-span shall be measured for each load increment and each load decrement and 5 minutes after the loads have been removed.
(f) Steps (c) to (e) shall be repeated.
(g) Load-deflection graphs shall be plotted.

Reporting of results

16.2.4 The following shall be reported:

(a) Details of the precast unit, including place of manufacture.
(b) The age of the concrete in the precast unit at the time of the test.
(c) The loads applied to the nearest 2% of the specified test load.
(d) The deflections measured to the nearest 0.5 mm.
(e) The load-deflection graphs.
(f) Details of any cracks.

(g) That the test method used was in accordance with this Specification.
APPENDIX 16.3

DETERMINATION OF THE RECOVERY VALUE AND REDUCTION IN MASS, AND THE EXTRUSION OF JOINT FILLER

Scope 16.3.1 This method covers the determination of the recovery value and reduction in mass of joint filler by the compression and recovery test, and the extrusion of joint filler by the extrusion test.

Apparatus 16.3.2 The following apparatus is required:

(a) Equipment for measuring the plan dimensions of the joint filler, accurate to 0.5 mm.

(b) Equipment for measuring the thickness of the joint filler, accurate to 0.1 mm.

(c) A balance, accurate to 0.1% of the specimen mass.

(d) A compression test machine complying with BS 1610 with auxiliary platens 100 mm x 100 mm and a minimum thickness of 13 mm.

(e) An extrusion mould open on one side only and rigidly fixed to a base plate. The mould shall be 100 mm x 100 mm (+0.5 mm, -0 mm) internally and shall be of sufficient depth to test the specimen. The mould shall be provided with a close fitting pressure plate that shall fit without binding and with a horizontal measuring dial gauge or device readable and accurate to 0.1 mm.

Procedure: compression and recovery test 16.3.3 The procedure for determination of the recovery value and reduction in mass by the compression and recovery test shall be as follows:

(a) Four specimens from the sample shall be prepared, each 100 mm x 100 mm (± 2.5 mm).

(b) The thickness (t₁) of the four specimens shall be measured to the nearest 0.1 mm, and two specimens shall be weighed to within 0.1% of their mass (m₁).

(c) Each specimen shall be subjected to three applications of load in the compression test machine at 24-hour intervals. During each application of load the specimen shall be compressed to 50% of its original thickness at a rate of strain of 1.3 mm per minute. The load required to achieve the compression shall be at least 0.07 N/mm² and shall not exceed 10 N/mm². The load shall be released immediately the specified amount of compression is reached.

(d) After the third application of load, a recovery period of 30 minutes shall be allowed and the thickness (t₂) of each specimen shall be measured to the nearest 0.1 mm.

(e) The two previously weighed specimens shall be re-weighed to within 0.1% of their mass (m₂).
Procedure: extrusion test

16.3.4 The procedure for determination of the extrusion by the extrusion test shall be as follows:

(a) One 100 mm x 100 mm (± 0.5 mm) specimen shall be prepared.

(b) The thickness of the specimen shall be measured to the nearest 0.1 mm.

(c) The specimen shall be placed in the extrusion mould and subjected to one application of load as stated in Clause 16.3.3(c). The extrusion at the open side of the mould shall be measured to the nearest 0.1 mm with the gauge or device when the specimen is compressed to 50% of the original thickness and before the load is released.

Calculation

16.3.5 (1) The recovery value (R) of each specimen shall be calculated from the equation:

\[ R = \frac{t_2}{t_1} \times 100\% \]

where:

- \( t_1 \) is the original thickness of the specimen (mm)
- \( t_2 \) is the thickness of the specimen after the third application of load (mm)

(2) The reduction in mass (M) of each specimen shall be calculated from the equation:

\[ M = \frac{m_1 - m_2}{m_1} \times 100\% \]

where:

- \( m_1 \) is the original mass of the specimen (g)
- \( m_2 \) is the mass of the specimen after the third application of load (g)

Reporting of results

16.3.6 The following shall be reported:

(a) Type and source of filler.

(b) The recovery values to the nearest 0.5%.

(c) The reductions in mass to the nearest 0.1%.

(d) The extrusion to the nearest 0.1 mm.

(e) That the test methods used were in accordance with this Specification.