SECTION 3
CONCRETE WORKS

3.1 GENERAL

The prevailing standard for all concrete work shall be BS 8110 and such amendments as shall be approved by the Engineer in accordance with the CIRIA Guide to Concrete Construction in the Gulf Region.

Concrete work shall consist of furnishing all materials and constructing structures of the forms, shapes and dimensions shown on the Drawings or as directed, using Portland Cement concrete, in accordance with the details shown on the Drawings and these Specifications.

Portland Cement concrete shall consist of a mixture of Portland Cement, fine aggregate, coarse aggregate, water and additives when required. The mixture shall be proportioned, mixed, placed and cured in accordance with the requirements of BS 8110: Part 1. Where an additional clause conflicts or is inconsistent with the requirements of BS 8110 the additional clause shall always prevail. The concrete mixes shall be designed mixes for special or ordinary concrete as defined in BS 8110, the design requirements of which are laid down in this Specification.

3.2 MATERIALS

3.2.1 Cement

3.2.1.1 General

Only Sulphate Resisting Cement as specified in Clause 3.2.1.3 shall be used unless otherwise directed.

Unless otherwise approved by the Engineer all cements shall comply with the following requirements:-

- The acid soluble alkali level measured as Na₂O + 0.658 K₂O shall not exceed 0.6% by weight determined by the test method described in BS EN196-21.

- The specific surface (fineness) shall not be greater than 325 m²/Kg and not less than 225 m²/Kg when tested as described in BS EN196-6.
The cement shall be of approved manufacture and shall be delivered in bags with seals unbroken, or delivered in bulk in approved containers which shall bear the manufacturer’s name, cement type and the date of manufacture. Test certificates from the manufacturers or suppliers shall be submitted for each consignment and shall indicate the results of the tests for compressive strength, setting time, soundness and fineness carried out in accordance with the requirements of the relevant BS or ASTM standards. Further tests may be required by the Engineer after the cement is delivered and stored on the site. The failure of any sample to satisfy the BS or ASTM requirements shall entitle the Engineer to reject the entire consignment from which it was taken.

Cement shall be stored immediately upon receipt at site in such a way to keep it away from water and moisture at all times. The Contractor shall provide a method statement for the storage of cement which shall be approved and implemented before any cement is delivered to site.

Consignments shall be used in the order in which they were delivered. Any consignment not used within 2 months from the date of manufacture will not be allowed to be used in the Works.

No cement from any consignment shall be used in Permanent Works without the approval of the Engineer. Cement which the Engineer considers to have deteriorated in any way shall not be used and shall be removed from site without delay.

One brand only of cement as approved by the Engineer shall be used throughout the Works unless otherwise authorised by the Engineer in writing. Differing types of brands shall not be mixed together for use in the Works.

3.2.1.2 Ordinary Portland Cement

Ordinary portland cement (OPC) shall comply with BS 12 or ASTM C150 Type 1. The tricalcium aluminate content shall lie within the range of 4% to 13%. The heat of hydration shall not exceed 290 Kj/Kg at 7 days when tested in accordance with ASTM C186.
3.2.1.3 **Sulphate Resisting Cement**

Sulphate resisting cement (SRC) shall comply with BS 4027 or ASTM C150 Type 5. The heat of hydration shall not exceed 290 Kj/Kg at 7 days when tested in accordance with ASTM C186. The strength class shall be ASTM Type V with average compressive strength (N/mm²) for mortar cubes of 15 and 20 at 7 and 28 days respectively.

3.2.1.4 **Moderate Sulphate Resisting Cement**

Moderate sulphate resisting cement (MSRC) shall comply with ASTM C150 Type 2 but containing not less than 4% and not more than 8% proportion by weight of tricalcium aluminate. In either case the cement shall not contain more than 2.7% proportion by weight of sulphur trioxide.

3.2.2 **Fine Aggregate for Concrete and Mortar**

Fine aggregate for concrete shall consist of natural screened and washed sand or crushed sand having hard and durable particles, or of other inert materials with similar characteristics. It shall not contain harmful material such as salts, clay lumps, tree roots, shale, iron pyrites, coal, mica, organic matter or any deleterious matter which may attack the reinforcement, in such a form or in sufficient quantity to affect adversely the strength and durability of the concrete. If necessary, the aggregate shall be washed and sieved to remove the deleterious substances. Beach sand shall not be permitted for use in concrete mixes.

The fine aggregate shall comply in all respects with the requirements of BS 882 and shall also comply with Dubai Municipality Administrative Order No. 143/91. In addition to the above, fine aggregate for concrete shall meet the requirements in Table 3-1.
### Table 3-1. Limits for Properties of Fine Aggregates for Concrete

<table>
<thead>
<tr>
<th>Type</th>
<th>Test Method</th>
<th>Permissible Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Magnesium Sulphate Soundness (5 Cycles)</td>
<td>ASTM C88</td>
<td>Max. 12%</td>
</tr>
<tr>
<td>2. Clay Lumps and Friable Particles</td>
<td>ASTM C142</td>
<td>Max. 1% by weight</td>
</tr>
<tr>
<td>3. Organic Impurities</td>
<td>ASTM C40</td>
<td>Lighter than standard</td>
</tr>
<tr>
<td>4. Material Finer than 0.075 mm</td>
<td>ASTM C117</td>
<td>Max. 3%</td>
</tr>
<tr>
<td>5. Acid Soluble Chlorides (Cl)</td>
<td>BS 812: Part 117</td>
<td>Max. 0.03%</td>
</tr>
<tr>
<td>For reinforced concrete made with:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPC &amp; MSRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For mass concrete made with:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPC &amp; MSRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For prestressed concrete and heat-cured reinforced concrete</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Acid Soluble Sulphates (SO₃)</td>
<td>BS 812: Part 118</td>
<td>Max. 0.3% by weight of fine aggregate</td>
</tr>
<tr>
<td>7. Water Absorption</td>
<td>ASTM C128</td>
<td>Max. 2.3%</td>
</tr>
<tr>
<td>8. Specific Gravity (apparent)</td>
<td>ASTM C128</td>
<td>Min. 2.6</td>
</tr>
<tr>
<td>9. Sand Equivalent (when aggregate other than natural sand is approved)</td>
<td>ASTM D2419</td>
<td>Min. 75</td>
</tr>
</tbody>
</table>
Fine aggregate of fine grading (BS 882) shall not be used. Fine aggregate shall conform to one of the gradings given in Table 3-2 (reproduced from BS 882).

### Table 3-2. Grading of Fine Aggregate for Concrete

<table>
<thead>
<tr>
<th>BS 410 Test Sieve (mm)</th>
<th>Percentage by Weight Passing BS Sieve</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coarse</td>
</tr>
<tr>
<td>10</td>
<td>100</td>
</tr>
<tr>
<td>5</td>
<td>100</td>
</tr>
<tr>
<td>2.36</td>
<td>60 - 100</td>
</tr>
<tr>
<td>1.18</td>
<td>30 - 90</td>
</tr>
<tr>
<td>0.60</td>
<td>15 - 54</td>
</tr>
<tr>
<td>0.30</td>
<td>5 - 40</td>
</tr>
<tr>
<td>0.15</td>
<td>0 - 15</td>
</tr>
</tbody>
</table>

#### 3.2.3 Coarse Aggregate for Concrete

Coarse aggregate for concrete shall consist of natural gravel, crushed gravel, or crushed stone, free from coating of clay or other deleterious substances. It shall not contain harmful materials such as salts, iron pyrites, coal, mica, laminated materials, tree roots, shale, or any materials which may attack the reinforcement, in such a form or in sufficient quantity to affect adversely the strength and durability of the concrete. If necessary, coarse aggregate shall be washed to remove deleterious substances.

The coarse aggregate shall comply in all respect with the requirements of BS 882. The coarse aggregate shall also fulfill the requirements in Table 3-3.

### Table 3-3. Limits for Properties of Coarse Aggregate for Concrete
<table>
<thead>
<tr>
<th>Type</th>
<th>Test Method</th>
<th>Permissible Limits</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Flakiness Index</td>
<td>BS 812: Part 105</td>
<td>Max. 25</td>
</tr>
<tr>
<td>2. Elongation Index</td>
<td>BS 812: Part 105</td>
<td>Max. 25</td>
</tr>
<tr>
<td>3. Ten Percent Fines Value or Impact Value</td>
<td>BS 812: Part 111</td>
<td>Min. 100KN</td>
</tr>
<tr>
<td></td>
<td>BS 812: Part 112</td>
<td>Max. 30%</td>
</tr>
<tr>
<td>4. Los Angeles Abrasion</td>
<td>ASTM C131/C535</td>
<td>Max. 30%</td>
</tr>
<tr>
<td>5. Shell content</td>
<td>BS 812: Part 106</td>
<td>Max. 3% by weight</td>
</tr>
<tr>
<td>6. Magnesium Sulphate Soundness (5 Cycles)</td>
<td>ASTM C88</td>
<td>Max. 12%</td>
</tr>
<tr>
<td>7. Clay Lumps and Friable Particles</td>
<td>ASTM C142</td>
<td>Max. 1% by weight</td>
</tr>
<tr>
<td>8. Material Finer than 0.075 mm</td>
<td>ASTM C117</td>
<td>Max. 1%</td>
</tr>
<tr>
<td>9. Acid Soluble Chlorides (Cl)</td>
<td>BS 812: Part 117</td>
<td></td>
</tr>
<tr>
<td>For reinforced concrete made with:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPC &amp; MSRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For mass concrete made with:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>OPC &amp; MSRC</td>
<td></td>
<td></td>
</tr>
<tr>
<td>For prestressed concrete and heat-cured</td>
<td></td>
<td></td>
</tr>
<tr>
<td>reinforced concrete</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10. Acid Soluble Sulphates (SO₃)</td>
<td>BS 812: Part 118</td>
<td>Max. 0.3% by weight of coarse Aggregate</td>
</tr>
<tr>
<td>11. Water Absorption</td>
<td>ASTM C127</td>
<td>Max. 2%</td>
</tr>
<tr>
<td>12. Specific Gravity (apparent)</td>
<td>ASTM C127</td>
<td>Min. 2.6</td>
</tr>
<tr>
<td>13. Drying Shrinkage</td>
<td>BS 812: Part 120</td>
<td>Max. 0.05%</td>
</tr>
</tbody>
</table>
The coarse aggregate shall conform to the gradings given in Table 3-4 in accordance with the nominal size of aggregate specified (reproduced from BS 882).

### Table 3-4. Gradings of Single Size for Coarse Aggregate

<table>
<thead>
<tr>
<th>Sieve Size (mm)</th>
<th>Percentage by Weight Passing BS Sieve for Nominal Sizes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>40 mm</td>
</tr>
<tr>
<td>50</td>
<td>100</td>
</tr>
<tr>
<td>37.5</td>
<td>85 - 100</td>
</tr>
<tr>
<td>20.0</td>
<td>0 - 25</td>
</tr>
<tr>
<td>14.0</td>
<td>-</td>
</tr>
<tr>
<td>10.0</td>
<td>0 - 5</td>
</tr>
<tr>
<td>5.0</td>
<td>-</td>
</tr>
<tr>
<td>2.36</td>
<td>-</td>
</tr>
</tbody>
</table>

#### 3.2.4 Combined Aggregate

Approved coarse aggregate and fine aggregate in each batch of concrete shall be combined in proportions as specified in BS 882 and as approved by the Engineer. However, in no case shall materials passing the 0.075 mm sieve exceed three (3) percent by weight of the combined aggregate.

The combined concrete aggregate gradation used in the work shall be as specified, except when otherwise approved or directed by the Engineer. Changes from one gradation to another shall not be made during the progress of the work unless approved by the Engineer.

Naturally occurring sand/gravel mixtures (all in aggregates) shall not be used unless otherwise directed by the Engineer.

#### 3.2.5 Water

##### 3.2.5.1 General

Water for washing aggregate and for mixing or curing of concrete shall be fresh, clean and substantially free from oil, acids, alkali, sewage, deleterious mineral or organic matter. Water shall comply in all respects with BS 3148. It shall not contain impurities in sufficient amounts to cause discoloration of the concrete.
All sources of water for use with cement shall be approved by the Engineer.

Sources of water shall be maintained at such depth and the water shall be withdrawn in such a manner as to exclude silt, mud, grass and other foreign matter. If at any time during construction the water from an approved source becomes unsatisfactory, the Contractor will be required to provide satisfactory water from some other source.

### 3.2.5.2 Specific Requirements

Water for washing aggregate and for mixing or curing of concrete shall be tested in accordance with BS and ASTM standards and shall meet the following requirements:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Maximum Concentration Limit</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Chlorides as Cl</td>
<td>250 mg/l</td>
<td>ASTM D512</td>
</tr>
<tr>
<td>2. Sulphates as SO₃</td>
<td>350 mg/l</td>
<td>ASTM D516</td>
</tr>
<tr>
<td>3. Alkali carbonates and bicarbonates</td>
<td>500 mg/l</td>
<td>ASTM D513</td>
</tr>
<tr>
<td>4. Total dissolved ions, including 1, 2 &amp; 3 above</td>
<td>2,000 mg/l</td>
<td>BS 1377: Part 3</td>
</tr>
<tr>
<td>5. pH</td>
<td>Min. 7/max. 9</td>
<td>ASTM D1293</td>
</tr>
</tbody>
</table>

The temperature of water for concrete should not be less than 5° C nor more than 25°C. Water may be cooled to not less than 5°C by the gradual addition of chilled water or ice but on mixing, no ice particles should be present in the mix. Alternatively, flaked ice may be used. The ice to be used should be crushed and should be the product of frozen water which complies with the above requirements.

### 3.2.6 Admixtures

Unless agreed by the Engineer neither admixtures nor cements containing additives shall be used.
Where the use of admixture had been agreed by the Engineer, they shall conform to the requirements of Type A, Type D, Type F or Type G as specified in ASTM C494 and shall be used in strict accordance with the manufacturer’s instructions. The Contractor shall be entirely responsible for the use of any approved admixtures. Samples of proposed admixtures shall, if required, be submitted to an approved testing authority by the Contractor in order to ascertain its suitability for use in the Works.

Approved methods and equipment shall be used for dispensing and incorporating the admixture into the concrete. The dispensing unit shall be designed so that the discharge of the admixture is visible.

The cost of such admixtures shall be included in the cost of concrete and no extra payment shall be made if they are used. The proportions of cement, fine aggregate and water shall be determined by the Contractor before concreting commences and submitted together with such test results as may be required to the Engineer for approval and the Contractor shall not commence concreting before such approval is given nor shall he alter or vary in any way the proportion of mix unless he submits fresh test results and mix proportions to the Engineer for approval.

The approval by the Engineer of such mix designs does not in any way absolve the Contractor of any of the requirements of the Specifications.

3.2.7 Concrete Mix Specification

The classes of concrete and their respective minimum cement content, consistencies and the minimum required compressive strengths shall be as shown:
Table 3-6. Concrete Classification and Mixes

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Comp. Strength (N/mm²)</th>
<th>Slump (mm)</th>
<th>Min. Ceme nt Content (kg/m³)</th>
<th>Max. Free Water/Ceme nt Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>7 days</td>
<td>28 days</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A (30/20/SRC)</td>
<td>20</td>
<td>30</td>
<td>25 - 75</td>
<td>310</td>
</tr>
<tr>
<td>B (25/20/SRC)</td>
<td>16</td>
<td>25</td>
<td>25 - 75</td>
<td>275</td>
</tr>
<tr>
<td>C (15/20/SRC)</td>
<td>10</td>
<td>15</td>
<td>25 - 100</td>
<td>250</td>
</tr>
</tbody>
</table>

The chloride and sulphate levels in the concrete mix shall comply with the requirements of Table 3-7.

Table 3-7. Maximum Limits of Chloride & Sulphate in Concrete Mix

<table>
<thead>
<tr>
<th>Type of Concrete</th>
<th>Chlorides as C1* (According to BS 1881:Part 124)</th>
<th>Sulphate as SO₃* (According to BS 1881:Part 124)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. For reinforced concrete if made with OPC/MSRC</td>
<td>0.30%</td>
<td>3.70%</td>
</tr>
<tr>
<td>if made with SRC</td>
<td>0.06%</td>
<td>3.70%</td>
</tr>
<tr>
<td>b. For mass concrete if made with OPC/MSRC</td>
<td>0.60%</td>
<td>3.70%</td>
</tr>
<tr>
<td>if made with SRC</td>
<td>0.12%</td>
<td>3.70%</td>
</tr>
<tr>
<td>c. For prestressed concrete and heat-cured reinforced concrete</td>
<td>0.10%</td>
<td>3.70%</td>
</tr>
</tbody>
</table>

*Maximum limits of chloride and sulphate content as a percentage by weight of cement in the mix.
The OPC and MSRC cements can also contain chlorides, the relevant standard BS 12 allows up to 0.1% C1. Therefore any chloride content present in the cement has to be taken into account while computing total C1 in the mix. In case the cement contains the maximum limit of 0.1% C1, then the aggregates, water and admixtures used for prestressed concrete or heat-cured reinforced concrete should be absolutely free of chlorides.

3.2.8 Cement Mortar and Grout

Unless otherwise specified, mortars and grouts shall be composed of Ordinary Portland Cement (satisfying Clause 3.2.1) and sand (satisfying Clause 3.2.2) in the following proportions:

<table>
<thead>
<tr>
<th>NOMINAL PROPORTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality</td>
</tr>
<tr>
<td>G 1</td>
</tr>
<tr>
<td>G 2</td>
</tr>
<tr>
<td>G 3</td>
</tr>
</tbody>
</table>

The amount of water (satisfying Clause 3.2.5) added shall just be sufficient to make the mortar or grout workable consistent with its purpose.

3.3 MIXING AND TESTING

3.3.1 Samples of Aggregates

Before any material from a particular source is used, the Contractor shall obtain representative samples of fine and coarse aggregates and carry out the necessary tests and analyses to show that the samples comply with the Specification. During the progress of the Works, the grading and chemical characteristics may be checked at frequent intervals. Sampling of aggregates shall be carried out in accordance with BS 812: Part 101 and Part 102.
The results of these tests shall be submitted to the Engineer and his approval shall be obtained before any of the material is used in the Works. Part of each sample will be required for concrete trial mixes and part shall be retained for comparison with subsequent deliveries.

No deliveries in bulk are to be commenced until such samples are approved by the Engineer as complying with this Specification.

3.3.2 **Trial Mixes for Concrete**

Following the Engineer's approval of the materials for each class of concrete, the Contractor shall prepare trial mix of each grade of concrete in the presence of the Engineer's Representative. Each trial mix shall comprise not less than 1/3 of a cubic metre of concrete and shall be mixed in an approved type of concrete mixer similar to that which the Contractor propose to employ on the Works. The quantities of all ingredients of trial mix including water shall be carefully determined by weight according to the approved mix design. Each trial mix shall show no tendency to segregate when handled and compacted by the methods by which the Contractor proposes to handle and compact the grade of concrete in the Works and it shall be capable of adequate compaction by such methods.

3.3.3 **Water/Cement Ratio**

The quantity of water to be added to the cement and aggregates during mixing shall be just sufficient to produce a workable mix to enable it to be well compacted and worked into corners of formwork and around reinforcement. All mixes shall be designed in respect of the proportioning of water so that the Slump Test as carried out according to BS 1881: Part 102 shall be in accordance with the requirements laid out in Clause 3.2.7. Measurement of water on the Site shall take into account the moisture present in the aggregates, and Slump Tests shall be taken frequently to ensure that variations in the moisture content of the aggregate are fully taken into account in determining the amount of water to be added.

3.3.4 **Measurement of Ingredients**

The aggregates for the concrete shall be measured by weight but measurement by volume may be allowed in special circumstances with the approval of the Engineer.
When the aggregates are to be measured by weight the weight batching machines shall be of a type approved by the Engineer's Representative. They shall be kept clean and in good condition and adjustment. At intervals as the Engineer's Representative may require, the Contractor shall check the accuracy of each weight-batching machine.

When the aggregates are to be measured by volume, the proportions of fine and coarse aggregates shall be measured in well constructed gauge boxes, of dimensions approved by the Engineer's Representative to guarantee that whole multiples of such gauge boxes will ensure the use of one more whole bags or containers of cement and the capacity of the concrete mixer shall be such as to ensure that no splitting of cement bags or containers is required. Gauge boxes shall be properly filled and struck off level, addition of fine aggregates to allow for bulking due to moisture content being made as required.

An efficient water measuring device shall be fitted to each concrete mixer.

Any cement container shall be such as to contain an accurately weighed amount of cement.

3.3.5 Mixing Concrete

The concrete shall be mixed in a power driven machine of the batch type, no hand mixing being allowed. The mixer shall be large enough to admit the use of 1 cement bag or container or whole multiples of bags or containers at a time. The mixing shall continue until there is a thorough distribution of the materials and the mass is uniform in consistency and colour. The period of mixing, judged from the time that all the ingredients including water are in the mixing drum shall be as ordered by the Engineer's Representative but shall not be less than 2 minutes or 20 revolutions of the drum whichever is the longer. Should there be for any reason a stoppage of greater than 30 minutes, the drum or other containers of the mixer shall be thoroughly washed and cleaned before mixing is resumed. On completion of the mixing the concrete shall be discharged onto clean boards or into clean barrows. The method of discharge from the mixer shall be such as to cause no segregation whether partial or otherwise of the concrete materials.
3.3.6 **Re-Mixing Concrete**

Concrete which has commenced to set shall not be remixed either with or without additional water and in no case shall such concrete be used in the Works.

3.3.7 **Concrete Testing**

3.3.7.1 **General**

The compression tests shall be performed on cubes 150 x 150 x 150 mm as described in BS1881: Part 116. Sampling, making test cubes and curing of cubes shall be in accordance with BS 1881: Parts 101, 108 and 111 respectively.

The following methods of testing shall apply to standard concrete cubes.

3.3.7.2 **Preliminary Testing**

After the materials have been approved and at least 10 days before any concrete is poured, the Contractor shall make 3 Nos. preliminary sets of test cubes. Each set of test cubes shall comprise of three cubes made from a single sample of concrete taken from the point of final discharge of the wet concrete. Each cube shall be made under the Engineer's Representative supervision. Cubes shall be tested as follows: one set shall be tested 7 days after the date of manufacture and one set 28 days after the date of manufacture. The third set will only be tested if the Engineer's Representative wishes to check the results of the tests on either of the other two cubes and shall otherwise be preserved by the Contractor until the end of the Period of Maintenance. Preliminary test cubes shall be made and tested for all grades of concrete and for all proposed variations of quality, quantity or origin of the aggregates and cement.

Should any of the test cubes crushed at 7 days or that crushed at 28 days fall below the specified requirements and the failure is confirmed by the testing of the third set, the Contractor shall, on the Engineer's Representative's instructions alter the mix design and/or the source of aggregates, cement or water and/or the method of mixing including alteration of the type of mixer. The compressive strength of the concrete cube at 7 days shall be equal to or more than two thirds the required compressive strength at 28 days.
3.3.7.3 **Works Testing**

During the course of the construction of the Works, the Contractor shall make test cubes as required by the Engineer's Representative. One set of six cubes will normally be taken from each individual concrete member, e.g. culvert invert, Irish crossings, but additional cubes shall be taken as directed by the Engineer's Representative. Three cubes will be tested at 7 days and three cubes at 28 days as the Engineer's Representative directs. Where the strength of the concrete is shown to be below that specified, the Contractor shall remove and replace at his own expense all concrete from the concerned pour. The Engineer may require the Contractor to cut out defective concrete from the Works at his own expense even though test cubes made from that concrete have not failed.

Durability tests of hardened concrete shall be carried out in addition to Splitting Tensile Test, Water Absorption Test, ISAT and Depth of Water Penetration test.

3.3.7.4 **Workability Testing**

The Contractor shall carry out slump test in accordance with BS 1881: Part 102 and/or compacting factor test in accordance with BS 1881: Part 103 at such frequency as the Engineer's Representative considers necessary to ensure that the workability and consistency of the concrete is maintained in accordance with the specified mix or accepted mix design and the trial mix. But in any case workability tests shall be carried out at least once every two hours during which concrete is being mixed.

3.3.8 **Frequency of Testing Aggregate and Concrete**

During the mixing and casting of concrete the frequency of testing for control purposes shall be as indicated in Table 3-8 or as directed by the Engineer's Representative. No direct payment is made for testing. The price of this work is to be included in the bid prices of concrete.
### Table 3-8. Required Frequency of Testing Aggregates & Concrete

<table>
<thead>
<tr>
<th>Type of Test</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grading of Fine and Coarse Aggregate; Flakiness and Elongation Index; Aggregate Crushing Value</td>
<td>Once for each source prior to approval and once prior to casting of each lift for any major concrete structure or as directed by the Engineer</td>
</tr>
<tr>
<td>Concrete Cube</td>
<td>One set (Min. 6 Cubes) from each mixer for class of concrete and at 10m³. The point of sampling of fresh concrete shall be at delivery into the construction unless otherwise directed by the Engineer. Each set of cubes shall be made from a separate batch.</td>
</tr>
<tr>
<td>Compacting Factor Test</td>
<td>As directed by the Engineer.</td>
</tr>
<tr>
<td>Transverse Strength (as per BS 7263 : Part 1)</td>
<td>As directed by the Engineer.</td>
</tr>
<tr>
<td>Absorption Requirement(^{(1)}) (as per BS 1881: Part 122)</td>
<td>As directed by the Engineer.</td>
</tr>
<tr>
<td>Slump Test</td>
<td>Once every hour from each mixer or as directed by the Engineer.</td>
</tr>
<tr>
<td>Mix Design</td>
<td>Once for each source of aggregate or every combination of sources or as directed by the Engineer.</td>
</tr>
<tr>
<td>Portland Cement</td>
<td>One 2 Kg sample for quality test shall be taken from each 1,700 bags or equivalent weight. Sampling of cement shall be as per BS EN-7</td>
</tr>
<tr>
<td>Water</td>
<td>A one gallon sample shall be obtained prior to use from, each source and at least every week for quality testing.</td>
</tr>
</tbody>
</table>

Note:  (1) Maximum 2% after 30 minutes
3.4 TRANSPORTING AND PLACING CONCRETE

3.4.1 General Requirements

Concrete shall be taken from the place of mixing to the place of depositing by approved methods which will prevent the segregation or loss of the ingredients and which are sufficiently rapid to ensure that the concrete does not commence to set before it is compacted in position. The concrete shall be deposited as near as possible to its final position in the Works and shall not be allowed to flow into position. Deposition of the concrete through chutes shall not be permitted and neither shall the concrete be dropped freely from a height exceeding 2.0 m. Pumping concrete through delivery pipes may be permitted but only with the prior approval of the Engineer's Representative.

No concrete shall be placed in a foundation until the extent of excavation and the character of bearing material have been approved and no concrete shall be placed in any structure until the placement of reinforcing steel and the adequacy of the forms and falsework have been approved.

The concrete shall be placed in its final positions as soon as possible after it has been mixed, and in any case before the initial set has taken place. The Contractor shall ensure that concrete which has already been placed in position and commenced to set is not disturbed by the placing or compaction of further concrete nearby. All concrete shall be carefully worked around and between reinforcement and all other embedded fittings without such reinforcement or fittings being disturbed. Concrete is to be worked well up against whatever surface it joints.

No concrete shall be mixed or placed when the light is insufficient, unless an adequate and approved artificial lighting system is operated and such night work is approved by the Engineer.

3.4.2 Placing Concrete in Hot Weather

Concrete shall only be placed where the general requirements in regard to ambient and mix temperatures laid down in the CIRIA Guide to Concrete Construction in the Gulf Region are met. The parameters laid down therein shall only be exceeded with the prior written consent of the Engineer.
Concrete shall not be placed when the shade air temperature exceeds 40° C or during periods of windblown dust or rain.

The temperature of batched concrete at time of placing shall not exceed 32°C unless otherwise specified.

Measures shall be taken to provide cool concrete and cool concreting conditions in order to reduce workability loss, premature drying of concrete and the development of high temperatures and temperature gradients in placed concrete.

Proposed measures must be described in method statements and may include:-

(a) Painting white or silver all storage vessels, hoppers, pipes, walls or roofs which contain or convey aggregates, cement or mixing water.

(b) Dampening the forms.

(c) Reducing the concrete temperature to the lowest practical level by procedures such as :-
   - Shading the aggregate.
   - Cooling the mixing water before use.
   - Screening the mixing plant and transporting vehicles from wind, rain and sun.

(d) Erecting wind breaks and sunshades at the concrete placing location.

(e) Reducing the time between the placing of the concrete and the start of curing to the minimum possible.

(f) Minimizing evaporation (particularly during the first few hours subsequent to placing the concrete) by suitable means such as applying moisture by fog spraying.

These measures are in addition to those specified for the curing of concrete.

In contracts which small structures spread over a large site, such as sewerage contracts, where transportation times could be large, dry mixing of concrete with addition of water immediately prior to placing may be proposed. Method statements for such a proposal must describe methods for accurate batching of water.
3.4.3 Placing Concrete in Water (Tremie Concrete)

Tremie concrete shall be deposited in water only if specified on the Drawings and/or directed by the Engineer and under the Engineer's supervision. Concrete to be deposited in water shall have the cement content increased by 25% at the Contractor's expense. Concrete shall be carefully placed in a compact mass in the space in which it is to remain by means of a tremie bottom dump bucket or other approved method that does not permit the concrete to fall through the water without adequate protection. The concrete shall not be disturbed after being deposited. No concrete shall be placed in flowing water and forms which are not reasonably watertight shall not be used for holding concrete deposited under water.

3.4.4 Blinding Concrete

Prior to placing any concrete on natural surfaces a blinding layer of Class C concrete shall be laid to a minimum of 75 mm thickness. This blinding shall be suitably curved prior to subsequent concrete placement. The blinding shall be clean and free from any dust or impurities prior to subsequent concrete placement.

3.5 COMPACTING CONCRETE

3.5.1 Tamping

All concrete shall be thoroughly compacted to the maximum with approved rammers without any segregation in its final position before it commences to set. Care shall be taken to ensure that the use of spade type rammers does not cause segregation of the aggregates and water. Initial compaction of slabs shall be with approved rammers and compaction by a screed board shall be limited to that required for the final shape and finish. During the placing and compaction of reinforced concrete, a competent steel mixer shall be in attendance to adjust and correct if necessary the position of the reinforcement.

3.5.2 Vibrating
Concrete shall be compacted by vibrating with an approved vibrator. The vibrators shall not be attached to any reinforcement or embedded fitting and where vibrators of the immersion type are used, care shall be taken to ensure that they do not come into contact with the reinforcement or embedded fittings. Freshly placed concrete shall not be vibrated in a manner likely to cause damage to concrete in other parts of the Works which has already taken its initial set. Concrete shall not be vibrated in such a manner and to such an extent as to cause segregation of the constituent materials. If shutter type vibrators are used they shall be augmented by immersion type vibrators if the thickness of the concrete member is more than 15 centimetres.

3.6 CURING OF CONCRETE

All concrete shall be protected from the harmful effects of sunshine, drying winds, rain, flowing water, or other adverse effect. For at least 7 days after placing, the concrete shall be prevented from drying out by being sprayed with fresh clean water and covered with hessian, clean sand or other approved material which shall be kept wet.

Whenever approved by the Engineer, membrane curing of concrete with an approved liquid may be used as an alternative to curing with water except that membrane curing liquid shall not be applied to surfaces of concrete from which the shuttering has been struck, until the concrete has been inspected and approved by the Engineer's Representative.

The concrete curing compound shall comply with the following requirements:

1) Only products which have been proved to be effective through extensive use shall be proposed and manufacturers’ literature shall include recent test certificates illustrating effective quality control and high curing efficiencies.

2) All materials shall be supplied in the containers marked by the manufacturer with his name, date of manufacture, shelf life, pot life and instructions for handling and application.

3) The liquid shall contain a white or silver colour pigment in sufficient quantity to give a uniform colour when applied to the concrete surface.
4) The liquid shall be of such chemical composition and consistency that it can be applied by an approved mechanical sprayer in fine spray to produce an even, uniform, impervious, continuous film within one hour of application which will not crack, peel or disintegrate within three weeks of application.

The compound shall not be poisonous, odorous or explosive and shall not react chemically with cement.

5) Curing compounds shall not be applied to surfaces to which further concrete or a surface finish is subsequently to be bonded unless the approval of the Engineer is obtained to the use of a water soluble type.

The Contractor shall ensure that all concrete is adequately protected against inclement weather until properly set and shall if necessary provide additional protection to that specified above.

3.7 JOINTS IN CONCRETE

3.7.1 Intervals During Concreting

The timetable for the depositing of concrete between construction joints should be so arranged that no face of concrete shall be left for more than 20 minutes before fresh concrete is deposited against it. Pauses for meals, servicing of machines, changes of shift, etc., and the distribution of concrete among the positions where work may be proceeding simultaneously must be carefully organized to ensure that the above mentioned interval shall not be exceeded.

3.7.2 Construction Joints

Construction joints shall be as shown on the Drawings or as directed by the Engineer's Representative. If the Contractor wishes to make additional construction joints he shall obtain the prior approval of the Engineer's Representative. Such approval may include the provision and placing of additional reinforcement at the Contractor's expense. Construction joints shall be formed by inserting temporary vertical stopping-off boards to form tongue and groove joint with the concrete placed subsequently except if separately detailed on the Drawings. Unless otherwise shown on the Drawings construction joints shall be
located as near as possible to the position of minimum shear and tensile stress in the concrete.

3.7.3 **Jointing Fresh to Set Concrete**

At a construction joint, the face of the previously placed concrete shall be cleaned of any skin or laitance or loose material by brushing with a wire brush or other approved method and washing with clean water. Insecurely held aggregate shall be removed. Excess water shall be removed and the surface while still wet shall be covered with 1:2 cement mortar which must be vigorously stippled into the surface by means of a suitable stiff brush, the depositing of the fresh concrete following closely.

3.7.4 **Expansion Joints**

Expansion joints shall be constructed at positions shown on the Drawings or as directed by the Engineer and shall be formed according to the instruction and dimensions shown on the Drawings.

Filled expansion joints shall be provided at every 6 m or as shown in the drawings and/or directed by the Engineer for the kerb and concrete backing. Any excavated surface for the concrete bedding should be watered and compacted to a minimum 95% of optimum density.

3.7.5 **Expansion Joint Filler**

Expansion joint filler shall be composed of approved durable non-extruding fibrous material suitably impregnated to prevent deterioration. Sheet bitumen fillers will not be accepted. Preformed strips of expansion joint filler shall be of such a nature as not to be permanently deformed or broken by twisting, bending or other normal handling on site. Samples shall be submitted for approval before ordering. The vertical expansion joints in kerbs and parapets shall be formed with approved vertical seal. Such vertical seal shall adhere to the vertical face sealed and shall not flow under maximum local sun temperature nor shall it be sticky to the touch.

1) Expansion joints for precast upstand kerbs shall be at 6 m.
2) For flush kerbs cast in-situ, at 2 m max.
3) For precast slabs, every 4 m min.
3.7.6 **Expansion Joint Sealing Compound**

The sealing compound shall be of an approved polysulphide compound, non-pouring grade for vertical application and pouring grade for horizontal application, as specified in Clause 9.2.1.2 (1) or it may be a rubber-bitumen compound.

The rubber-bitumen compound shall be a flexible weather resistant seal, slump resistant unaffected by permanent immersion in water, or by alkalis or sulphates. The material shall have a minimum storage life of 12 months in original containers stored in cool dry conditions and a density of 1.30 kg/litre.

The sealing compound shall adhere firmly to the concrete in all weather conditions. The sealing compound shall not flow either along or down the joint during hot weather. The sealing compound shall be durable and shall not weather beyond the forming of a thin surface skin.

Samples shall be submitted for approval before ordering. Vertical sealer shall be used with an approved priming compound. Application of the sealing compound shall be strictly in accordance with the Manufacturer's instructions.

3.7.7 **Waterstop Across Joints in Concrete Structures**

Seepage of water through any joints in a water retaining or water excluding concrete structure shall be prevented by the use of PVC Waterstop or other material as directed and approved by the Engineer. They shall be placed centrally as a water barrier across the designated joint in in-situ concrete structures and cast centrally into the edges of adjacent concrete components.

Waterstop shall be used at all Expansion and Contraction Joints in concrete structures below water table. For a Construction Joint, requirement of a waterstop shall be indicated in the drawing. The Engineer may also require the Contractor to provide waterstop at any additional Construction Joint approved at his request. Waterstop shall be extruded from high grade grey PVC Compound. Flat Dumbbell plain web waterstop shall be used for a Construction Joint while for an Expansion Joint or a Contraction Joint, a centre bulb waterstop shall be used. The width of the waterstop shall depend upon
the concrete thickness, the aggregate size and the position of reinforcement. In general, the following shall be taken as a guide to select the width, w, of a waterstop:–

\[ w < t, \text{ but } w > (6a+j) \]

where,  
\( t \) = concrete thickness  
\( a \) = largest aggregate size  
\( j \) = width of Expansion Joint

The following Technical Data shall apply:

- **Hardness**: 42 - 52 BS Softness degrees at 25°C.
- **Tensile strength**: 13.8 N/mm² minimum at 25°C.
- **Elongation at break**: 285% minimum at 25°C.

3.8 **INSPECTION OF CONCRETE**

The Contractor shall not proceed with the surface finish or making good of concrete surfaces until he has received the Engineer's Representative's permission to do so and he shall not apply cement slurry or mortar or any other coating to the concrete surfaces from which the shuttering has been struck until the concrete has been inspected and approved by the Engineer's Representative.

3.9 **FAULTY CONCRETE WORK**

The Contractor shall on the written instruction of the Engineer's Representative remove and reconstruct any such portion of the work which in the opinion of the Engineer's Representative is unsatisfactory as regards quality of concrete, incorrect dimension of the cast portion, badly placed or insufficient reinforcement, honeycombing or other such cause as shall render the construction not up to the standard required and which in the opinion of the Engineer may affect the strength or durability of the construction.

3.10 **REPAIRS TO CONCRETE**

The method of repairing and replacing defective concrete which the Contractor proposes to adopt shall be submitted to the Engineer's
Representative for prior approval and the repair shall be carried out in such manner as the Engineer may direct or approve.

3.11 SUPERVISION OF CONCRETE WORK

Throughout the progress of the concrete work the Contractor shall employ and provide such supervision as is necessary to ensure

(a) the day to day control of the quality of the concrete and

(b) the mixing, transporting, placing, compacting, curing and protection of the concrete, and

(c) the carrying out of all testing as specified herein and any further testing which the Engineer's Representative may require, and

(d) the conducting of investigations as the Engineer's Representative may require, and

(e) the preparation of reports and the keeping of such records as the Engineer's Representative may require.

3.12 FINISHING OF CONCRETE

All concrete surfaces (except top faces of culvert decks) not requiring shuttering shall be trowelled to a smooth dense surface with the minimum of cement and fine particles being brought to the surface and shall be free from irregularities. Top faces of culvert decks shall be carefully screeded and tamped to the required shape and to a dense surface with the minimum amount of cement and fine particles being brought to the surface and should be free from irregularities greater than 3 mm in height or depth.

Shuttered surfaces of concrete which will always be in contact with the ground may be cast against sawn timber. All other exposed shuttered surfaces including precast concrete shall be cast against steel, plywood or planed timber formwork and shall be carefully rubbed down with carborundum to remove all imperfections and irregularities. Surfaces which are honeycombed, porous or irregular and which in the opinion of the Engineer's Representative do not comply with the Specification shall be cut out and replaced with sound concrete as directed by the Engineer's Representative. The cost of all normal surface finishes and
making good shall be deemed to be included in the tendered rate for the concrete.

3.13 DESIGN AND CONSTRUCTION OF FORMWORK

3.13.1 General

Formwork shall in every respect be adapted to the structure and the required surface finish of the concrete. It shall include all temporary moulds for forming the concrete to the required shape and finish and for the support of such moulds. It shall be fixed in perfect alignment and securely ledged and braced so as to be able to withstand, without displacement deflection or movement of any kind, the weight of the construction and the movement of persons materials and plant. Joints shall be close enough to prevent the leakage of liquid and fine materials from the concrete.

The Engineer's Representative may at any time require the prior submission for approval of the Contractor's proposals for design and construction of formwork including supports. The formwork shall be constructed so as to permit its removal without damage to the concrete.

3.13.2 Spacing Blocks and Temporary Construction Ties

Internal spacing blocks and construction ties shall be avoided as far as, in the Engineer's Representative opinion, possible and practicable. Where it is intended that the spacing blocks or construction ties shall be removed whether before or after the concrete has set, the making good of the concrete shall be subject to the Engineer's Representative's approval. The removal of the blocks or ties must not jeopardise the stability of the construction. If, with the approval of the Engineer's Representative, the spacing blocks and construction ties are allowed to remain in the concrete then they shall be of such material and of such quality that they do not prejudice the strength of the work. Concrete spacing blocks shall be made of concrete at least equal in quality to the main concrete. Metal ties shall be positioned such that they do not come into contact with any of the reinforcement or fittings and no part of the tie shall be permanently embedded in the concrete nearer than 5 cm to the exterior surface of the concrete.

All holes shall be filled with 1:2 cement mortar.
3.13.3 Slab Forms

Where timber is used for the soffits of slabs, the boards shall be placed and laid perfectly true with close joints to prevent the percolation of liquid or fines from the concrete. Tongue and groove planks shall be used if specified. All requisite bearer and struts shall be adjusted in position and placed where necessary on bearers as specified in the case of beam forms.

3.13.4 Type of Formwork

3.13.4.1 Exposed Concrete Faces for Bridges

All concrete faces shall be left as struck with a fair face, true to line finish.

In order to have the finish as it will be formed, approved by the Engineer, test pieces of 1 sq.m vertical panel 25 cm thick shall be cast. After approval they shall be retained in position until the concrete works have been completed then they shall be demolished and removed from the Works.

After careful inspection, all superfluous fines and similar projections shall be carefully removed. No render or other applied finish shall be used to obtain a fair face to the concrete. All concrete faces to be exposed in the finished works shall be adequately protected against damage and surface staining during the execution of the Works.

3.13.4.2 Sawn Formwork

Shall be used for all culverts.

3.13.5 Preparation of Formwork for Concreting

Immediately before the concrete is deposited, the formwork shall be thoroughly cleaned out and freed from sawdust, shavings, wire cuttings, dust, sand, clay and all other deleterious and extraneous materials.
Temporary openings shall be provided in the formwork to facilitate this work. The inside surfaces of the formwork shall, immediately prior to final erection, be coated with mould oil. The mould oil shall be of approved type and shall be applied uniformly and the quantities used shall be the minimum consistent with its purposes. The Contractor shall ensure that all steel reinforcement and adjoining concrete surfaces are kept free of mould oil.

All formwork and reinforcement shall be clean and free from standing water immediately before placing concrete.

3.13.6 Approval of Formwork Before Concreting

The Contractor shall in all cases request the approval of the formwork by the Engineer's Representative in sufficient time to allow an inspection to be made and shall not commence concreting until such approval is obtained. The period between the Contractor's request for approval and his intention to commence concreting shall be not less than one clear normal working day and the Engineer's Representative may require a longer period if, in his opinion, the formwork is of such complexity as to require it.

Such approval shall not absolve the Contractor of his responsibilities under the Contract.

3.13.7 Removal of Formwork

All formworks shall be struck without jarring the concrete or subjecting the same to sudden shock.

Before striking any formwork, the Contractor shall satisfy himself that the concrete is sufficiently hardened to bear its own load and any other loads that may be placed on it.

No formwork is to be removed, if in the opinion of the Engineer's Representative, the concrete has not set sufficiently. approval of the Engineer's Representative shall not absolve the Contractor of his responsibilities under the Contract.

Subject to the above and the concrete test cube results, the minimum periods for the removal of formwork generally are as follows:
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Sides of beams, walls and columns - 2 days
Soffits of beams and slabs (props left in) - 7 days
Removal of props (beams and slabs) - 14 days
Soffits of precast beams - 7 days

(These times may be reduced only with the written approval of the Engineer)

In the case of the special types of formwork, striking times are to be approved by the Engineer.

If a beam slab is required to support a construction load in excess of its design load, the beam or slab is to be propped until the supported construction has reached the age when the propping may be removed.

No supports for the shuttering may be left in the finished concrete without the written permission of the Engineer.

3.13.8 Concrete Below Ground

All concrete placed below ground level shall have a minimum protection to its outside faces with a bituminous membrane as per Clause 9.2.1.2 of this Specification.

3.14 READY MIXED CONCRETE

3.14.1 Compliance with Specification

The use of concrete delivered to the Site in a plastic condition and ready for placing in its final position shall be permitted subject to the following conditions:

(a) The constituent materials and the concrete mix shall comply with the requirements of this Specification.

(b) The concrete shall be produced in accordance with the standards laid down in the current edition of the "Authorisation Scheme for Ready Mixed Concrete", published by the British Ready Mixed Concrete Association (B.R.M.C.A.), except that

(i) Para. 11.1 (i) of the above publication shall be replaced by item (d) below.
(ii) Water shall be added to the mix under the control of the central batching plant.

(iii) Dry batching with water added on site will not be permitted.

(c) The concrete shall be supplied by a depot approved by the Engineer and Dubai Municipality.

d) The concrete shall be placed in its final position and left undisturbed within 1-1/2 hours maximum of the time when the cement first comes into contact with wetted aggregates, i.e. the time when hydration of the cement commences. If the temperature is less than 4°C or if the temperature is above 21°C, this period shall be reduced to one hour.

e) The drum of the agitator truck shall be placed in its final position and left undisturbed within 1.5 hours maximum of the time when the cement first comes in contact with wetted aggregates, i.e. the time when hydration of the cement commences. If the temperature is less than 4°C or if the temperature is above 21°C, this period should be reduced to one hour.

f) The truck mixer should discharge concrete at approximately 0.5 m³ per minute. If this rate is not possible, it is advantageous for the concrete to be discharged as quickly as possible especially during high ambient temperature conditions. The concrete shall be delivered and completely discharged within 1.5 hours or before the drum has revolved 300 times after the introduction of water to the cement and aggregates.

g) In order to ensure the uniformity of mixing the following test, from ASTM Standard C94, shall be carried out:

(i) Samples of concrete shall be taken from about 1/6 and 5/6 points of a batch, and the differences in the properties of the two samples should not exceed any of the following:
Density of concrete calculated to an air-free basis – 16 kg/m³
Air content, volume % of concrete – 1%
Slump = 25 mm when the average is 100 mm, sand 40 mm when the average is 100 mm to 150 mm
Percentage retained on 5 mm sieve – 6%
Density of air-free mortar – 1.6%
Compressive strength, average 7-day strength – 7.5%

h) All the material for the concrete shall pass the specification requirements and concrete shall be verified with DM-DCL

3.14.2 **Pumping Concrete**

Pumped concrete is defined as concrete that is conveyed under pressure either through rigid or flexible hose, and discharged directly into the desired area. Pumping may be used for almost all concrete construction but is especially useful where there is inadequate space for other concrete placing equipment to be operated.

A steady supply of pumpable concrete is necessary for satisfactory pumping. Pumpable concrete, like conventional mixes, requires good quality control; i.e., properly graded uniform aggregates, and materials uniformity and consistently batched and thoroughly mixed.

3.14.3 **Field Control**

Quality concrete in the field is the ultimate objective to be attained; a high level of quality control must be maintained. The locations at which samples for testing the concrete are taken is extremely important. Sampling according to ASTM C94, is for the acceptability of the ready-mixed concrete. However, the quality of the concrete being placed in the structure can only be measured at the placement end of the pipeline. Where appropriate, sampling at both the truck discharge and point of final placement should be employed to determine if any changes in the slump, air content, and other significant mixture characteristics occur. When sampling at the end of the placement line, great care should be taken to ensure that the sample is representative of the concrete going into the placement. Changing the rate of placing and/or the boom configuration can result in erroneous test results.

3.14.4 **Remixing**
Fresh concrete that is left to agitate in the truck mixer tends to stiffen before initial set develops. This concrete shall not be used if the following conditions apply; (1) the maximum water to cement ratio will be exceeded, (2) the maximum slump will be exceeded, and (3) the maximum number of revolutions or mixing time to placement time will be exceeded.

3.14.5 Documentation

The Engineer shall receive copies of the delivery tickets for each batch of concrete, and have access to a site record book maintained by the Contractor in which the following information is recorded for each batch of concrete delivered:

(i) Delivery ticket number.

(ii) Slump of the concrete, testing on site immediately prior to placing.

(iii) Time when concrete is placed in position and left undisturbed.

(iv) Location that the concrete is placed.

(v) Works test cube reference.

3.15 REINFORCEMENT STEEL

3.15.1 General

This work shall consist of furnishing, fabricating and placing steel reinforcement bars of the grade, type, quality, size, shape and quantity
designated, all in accordance with these Specifications and the details shown on the Drawings.

The Contractor shall be responsible for furnishing reinforcing steel in sufficient quantity and of the proper sizes, lengths and shapes shown on the Drawings for any given structure.

3.15.2 Material Specifications

All reinforcement bars shall be of a deformed type in accordance with BS 4449, except that plain bars may be used where specifically indicated on the Drawings. Plain bars shall be in accordance with BS 4449.

All steel reinforcement shall conform to the requirements of the Specifications for Deformed High Yield Steel Bars, Grade 460 Type 2, unless otherwise shown on the Drawings or specified by the Engineer.

Mild steel where specified or called for shall be either deformed or plain bars complying with ASTM A615 structural grade or BS 4449 or any equivalent National Standard as directed and approved by the Engineer.

Tying wire shall be No.16 gauge soft annealed iron wire or No. 18 gauge stainless steel wire or the equivalent AASHTO specification for tying wire.

Welded wire fabric shall be used as reinforcement for concrete where shown on the Drawings and as directed. Welded wire fabric shall conform to the requirements of AASHTO M55 or to BS 4483.

All reinforcement shall be protected against corrosion with a fusion-bonded epoxy coating in accordance with the requirements of ASTM A775/A775M and BS 7295.

The Contractor shall be responsible for obtaining the Engineer’s approval to the steel bars prior to coating commencing. Such approval will in no way relieve the Contractor of his responsibilities under the Contract.
The frequency of sampling and method of quality control shall be in accordance with BS 4449 latest edition.

For steel reinforcement, please refer to clause 4/8 “Reinforcing Bars” of Section 4 – Concrete Works of DM Roads Dept. General Specification.

The Contractor shall furnish to the Engineer a certificate of compliance for each shipment of coated steel bars. The certificate of compliance shall state that representative samples of the coated bars have been tested and that the test results comply with the requirements of the Specifications.

3.15.3 Construction of Reinforcement

Steel reinforcing shall be stored on timber packing clear of the ground. The steel bars shall be free from sharp deformations, rolled-in silvers, deep recesses or surface faults/blemishes which could result in inefficient or inadequate coating. When fixed in the work and immediately prior to concreting, steel reinforcing shall be entirely free from loose mill scale, loose rust, oil, grease, paint, mould oil, and all other deleterious and extraneous material. All hooks, bends, etc., unless otherwise shown on the Drawings shall be to BS 4466.

Before ordering reinforcing steel, the Contractor shall prepare bar bending schedules at his own cost and submit them to the Engineer for his approval. Bar schedules shall show the weight of each bar, the total weight of each bar size and the total weight of bars, and bending diagrams for bars in accordance with BS 4466. The length of each bar shall be calculated in accordance with BS 4466 except that the minimum internal bending radius shall be four times the bar diameter. The Contractor shall also provide and submit to the Engineer for approval any working drawings additional to the Contract Drawings which may be found necessary for the production of bar bending schedules or for the completion of the Works.

The Engineer’s approval of the Contractor’s working drawings and bar bending schedules shall in no way relieve the Contractor of responsibility for the correctness of such drawings or schedules.

Steel reinforcement shall be bent accurately to the shapes and dimensions shown on the approved bar bending lists or drawings. Bars shall be bent round mandrels of the requisite diameter.
Steel reinforcement shall be cut and bent in accordance with BS 4466. Cutting or bending by the application of heat is not permitted. Welding of reinforcement shall only be permitted when approved in writing by the Engineer. If such approval is given then the workmanship shall be in accordance with BS 5135. The Contractor shall submit full technical details of his proposed procedures prior to seeking approval.

Hot rolled high yield bars shall not be straightened or bent again, having once been bent. If the Engineer gives approval to bend mild steel reinforcement projecting from the concrete, the internal radius of bend shall not be less than four times the nominal size of the bar.

Links, hoops, stirrups are generally to be bent round pins of the same diameter as the bars they are to embrace. Where however, such bars are less in diameter than twice the diameter of the link, the radius of the bend shall be equal to the diameter of the link.

3.15.3.1 Placing Reinforcement

The number, size, form and position of all reinforcement shall, unless otherwise directed or authorized by the Engineer, be strictly in accordance with the Drawings. Nothing shall be allowed to interfere with the disposition of the reinforcing bars. Bars generally must be of the required lengths. Welding of the bars will not be permitted. Lapping of the bars other than the lap splices shown on the Drawings should be avoided. The Engineer may approve certain lappings under special conditions. All lappings should comply strictly with the AASHTO specifications, namely Article 1.5.6. Clause "e".

The steel reinforcement shall be firmly held in position by wire ties and concrete blocks or other approved spacers designed to maintain the correct clear cover of concrete over steel reinforcement. They shall be as small as possible consistent with their purpose, and of a shape acceptable to the Engineer. Minimum cover to reinforcement shall be 50 mm unless otherwise detailed. The position of spacers and their method of use shall be approved by the Engineer. The steel reinforcement shall be so connected as to form a rigid cage.

All intersecting bars shall be bound together with No.16 gauge soft iron wire with the ends of the wire turned into the main body of the concrete.
3.15.3.2  Maintaining Reinforcement in Position

Concrete distance blocks shall, unless otherwise directed, be used between the reinforcement and the bottom and sides of the forms to ensure correct placing and cover of the bars. The strength of such concrete distance blocks shall be not less than that of the main concrete. The greatest care shall be taken to prevent any displacement or bending of the members of the reinforcement adjusted and temporarily fixed in position before commencement of the concreting. Reinforcement temporarily left projecting from the concrete at construction of other joints shall be adequately protected against displacement both during concreting and afterwards and shall not be bent out of position unless agreed by the Engineer's Representative. During the concreting competent steel fixer shall be in attendance to re-set any reinforcement inadvertently displaced.

3.15.3.3  Approval of Reinforcement Before Concreting

The Contractor shall in all cases request the approval of the Steelwork by the Engineer's Representative in sufficient time to allow an inspection to be made and shall not commence concreting until such approval is obtained. The period between the Contractor's request for approval and his intention to commence concreting shall not be less than one clear normal working day and the Engineer's Representative may require a longer period if, in his opinion, the reinforcement is of such complexity as to require it.

Such approval shall not absolve the Contractor of his responsibilities under the Contract.

3.16  PRECAST CONCRETE KERBS, EDGINGS & QUADRANTS

Precast concrete kerbs and edgings shall be hydraulically pressed and they and precast concrete quadrants shall comply with the requirements of BS 7263: Part 1 and to the dimensions and shapes shown on the Drawings and/or as directed by the Engineer. They shall be Class B concrete with sulphate resisting cement as indicated in Clause 3.2.7 of
this Specification. They shall be uniform in colour free from cracks, flaws or other defects with well defined arises.

The kerbstones shall be 900 mm long or as directed by the Engineer's Representative. Samples of kerbstones proposed to be used shall be submitted to the Engineer for his approval prior to order or manufacture. Kerbstones shall not be used before they have been inspected and approved by the Engineer. They shall be fully cured when delivered to site (28 days min.).

Kerbstones shall be laid on concrete Class C bedded on 1:3 sand cement mortar as specified and/or as directed by the Engineer. All kerbstones shall be well bedded and settled in place true to line and level with a suitable wooden mould. Before kerbstones shall be approved it should be ensured that their top surfaces are in a uniform plane and their front faces are in correct alignment. Any kerbstones not satisfying these requirements or having cracked or broken arises or faces shall be removed and replaced or reset as instructed by the Engineer.

Joints between kerbstones shall be not less than 3 mm nor greater than 5 mm in width and shall be uniform from top to bottom. Joints shall be left open.

Where precast kerbs of straight section are laid to form radii, joints should be filled with non-shrinkage mortar, and expansion joints (using flexel or similar joint filler) shall be provided at 3 m centres. For radii of 10 m or less quadrants shall be used. Kerbs of a reduced size shall only be used for this condition where approved by the Engineer.

Tolerance in top level of kerbstones and horizontal alignment shall be ± 3 mm.

All kerbstones shall be painted alternately black and white. The paint shall be an approved concrete paint giving a nominal thickness of 100 microns in two applied coats.

Tranverse strength and Water Absorption shall be in accordance with BS 7263 : Part 1.

3.17 IN-SITU CONCRETE EDGING
In-Situ concrete edge strips shall be to the cross section shown on the drawings and the class of concrete made with sulphate resisting cement indicated thereon in accordance with Clause 3.2 of this Specification.

The edge strip shall be formed in as long lengths as possible and the form work shall be set on the top surface of the sub-base, set to produce the line and level in accordance with the requirements of this Specification. Care must be taken to ensure that the top surface is carefully finished to achieve these requirements and to provide the control of the wearing course. Expansion joints will be provided with an approved joint filler at maximum 3 m centres as shown on the drawing and/or as directed by the Engineer. The kerb shall be protected against covering or splashing by bitumen or cement.