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SECTION 5.01  CONCRETE MIXES AND TESTING

5.01.1  SCOPE

The works covered in this Section consists of the specifications for concrete materials including sampling, testing and storage of such materials, concrete strength requirements, concrete testing procedures and requirements and job mixes.

5.01.2  MATERIALS

A.  Cement

A.1  Cement shall be Portland cement, originating from manufacturers approved by the Engineer and shall comply with BS EN 197-1:2000 for Ordinary Portland Cement and with BS 4027:1996 for Sulphate Resisting Portland Cement.

A.2  Only one type or brand of cement shall be used in any one structural member. Mixing of types or brands shall not be permitted.

A.3  All cement shall be subject to approval and shipments of cement shall be accompanied by a manufacturer's Certificate of Guarantee and a laboratory test certificate. Approval of any cement sample shall not relieve the Contractor of the responsibility to fabricate concrete of the specified quality and strength.

A.4  When factory or field tests subsequent to original approval tests show that the cement no longer complies with the Specifications, the entire consignment from which the sample was taken shall be rejected and the Contractor shall immediately remove the rejected material from the Site and replace it with cement meeting the required specifications.

A.5  Whenever low alkali cement is specified, the total alkali content, expressed as the sodium oxide equivalent, shall not exceed 0.6% by weight. Approval of any cement sample shall not relieve the Contractor of the responsibility to fabricate concrete of the specified quality and strength.

A.6  If local test certificates are not available the Contractor shall obtain from each proposed manufacturer a typical sample of cement which shall be fully and independently tested in accordance with the appropriate standard and the results submitted for approval. Primary and secondary sources of the required cement shall be given. All costs associated with the testing shall be allowed for by the Contractor.

A.7  Details shall also be submitted of the manufacturer's name, the address of the source of production, the manufacturer's description of the cement type and brand name and the standards to which compliance is guaranteed.

A.8  Average values and corresponding maximum and minimum values of the following cement composition and properties shall be submitted, covering a continuous
production period of at least 6 months and ending not earlier than 3 months before submission of the data. The Contractor shall state if any material or production process changes have been made since the end of the above period; if any are proposed details shall be provided.

<table>
<thead>
<tr>
<th>Composition</th>
<th>Properties</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insoluble residue</td>
<td>Lime saturation factor (LSF)</td>
</tr>
<tr>
<td>Silica (SiO₂)</td>
<td>Alumina-iron ratio (A/F)</td>
</tr>
<tr>
<td>Alumina (Al₂O₃)</td>
<td>Tri-calcium aluminate (Ca₃A₁)</td>
</tr>
<tr>
<td>Total Iron (Fe₂O₃)</td>
<td>Free lime in clinker (as CaO)</td>
</tr>
<tr>
<td>Calcium (CaO)</td>
<td>Total acid solution alkalis</td>
</tr>
<tr>
<td>Magnesium (MgO)</td>
<td>Heat of hydration</td>
</tr>
<tr>
<td>Potassium (K₂O)</td>
<td>- at 7 days</td>
</tr>
<tr>
<td>Sodium (Na₂)</td>
<td>- at 28 days</td>
</tr>
<tr>
<td>Sulphate (SO₃)</td>
<td>Fineness (m²/kg)</td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td>Setting times</td>
</tr>
<tr>
<td>Chloride (Cl)</td>
<td>- Initial (min)</td>
</tr>
<tr>
<td>Loss on ignition</td>
<td>Soundness (mm)</td>
</tr>
<tr>
<td></td>
<td>Compressive strength</td>
</tr>
<tr>
<td></td>
<td>- 3 days</td>
</tr>
<tr>
<td></td>
<td>- 7 days</td>
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<tr>
<td></td>
<td>- 28 days</td>
</tr>
<tr>
<td></td>
<td>- 3 months</td>
</tr>
</tbody>
</table>

A.9 The requirements of item A.8 shall only be modified or dispensed with at the discretion of the Engineer and if such dispensation is given in writing.

A.10 The manufacturer's bulk average test certificate for each consignment of cement shall be submitted, showing the results for chemical composition and physical properties determined in accordance with the relevant standard. Samples shall be taken for each consignment of cement and tested as directed by the Engineer by an approved independent laboratory and at the Contractor’s expense.

A.11 Where bulk cement deliveries are proposed, the Contractor shall provide all information required by the Engineer concerning off-site storage and loading arrangements and facilities for the Engineer to inspect these arrangements for approval purposes shall be provided. Consignments shall be used in the order in which they are delivered.
A.12 Storage capacity shall be sufficient to meet the schedule of work so that continuous work is achieved. Cement shall be stored in moisture-proof storage sheds. Stale, caked, reclaimed or re-sacked cement shall not be used. The Contractor shall not store cement in areas subject to flooding.

A.13 Cement remaining in bulk storage at the mill for more than 6 months or cement stored in bags in local storage by the Contractor or a vendor for more than 3 months after shipment from the mill shall be retested before use and shall be rejected if it fails to meet any of the requirements of these specifications.

B. Aggregates

B.1 Proposed aggregate sources shall be examined by the Engineer who shall check the following:
- Name, location, grid reference, type of deposit, potential variability, methods of extraction.
- Methods and degree of control exercised over extraction.
- Processing methods, types of plant, number of processing stages, standards of maintenance and process control, producer's laboratory facilities and technical staffing.
- Stockpiling arrangements, loading and supply arrangements.
- Potential variations in end-products due to variations inherent in the deposit and in the existing methods of extraction, processing and stockpiling.
- Modifications to existing extraction, processing, storage and handling arrangements, and to supervision arrangements to reduce end-product variations.
- Requirements for supplementary processing on site.

B.2 The Contractor shall provide photographs of each of the proposed new sources and related production arrangements. The source photographs shall include low level aerial photographs and close-ups of working faces.

B.3 Aggregate deposits shall be sampled and tested in a systematic manner to assess their potential variability and to assist in determining appropriate methods of extraction and processing.

B.4 The deposit investigation and sampling programmes shall be relevant to each type of deposit and shall be devised and supervised by an experienced engineering geologist approved by the Engineer. The engineering geologist shall make a field reconnaissance of the potential deposit areas and the existing workings.

B.5 Each size of aggregate shall be sampled at the discharge points on the production plant (i.e. conveyors or hoppers, not stockpiles) at three well spaced intervals during the course of each of three consecutive production days; these samples shall be designated "production samples".
B.6 Samples shall be taken from producer's stockpiles of any materials with visible variations in physical characteristics or appearance and materials ready for loading. These samples shall be designated "stockpile samples".

B.7 All samples shall be taken by arrangement with and in the presence of the Engineer or his representative and shall be tested in accordance with these specifications.

B.8 All samples shall split for independent testing by the Contractor and the Engineer. These samples shall be retained on site.

C. Testing Aggregates

C.1 Each production sample shall be tested for the following:
- Proportion of natural (uncrushed) material (% by weight) passing a 75mm sieve.
- Total acid soluble chloride content and total acid soluble sulphate content (% by weight).
- Flakiness and elongation indices.

C.2 Aggregates from all production sources shall be combined (by equal weight) to form composite production samples for each size of aggregate. The composite samples and the individual production samples shall be tested for the following:
- Potential Reactivity tests for alkali-silicate and alkali-carbonate reactions: petrographic examination in accordance with BS 812-104:1994 or ASTM C295, rapid chemical method in accordance with ASTM C289 and rock expansion test in accordance with ASTM C586. If one or more of these tests are positive then the mortar prism test in accordance with ASTM C227 shall be carried out.
- Partial chemical analysis, including insoluble residue (ASTM D3042-84), chloride content, sulphate content and calculated approximate composition.
- ASTM Soundness Test C88, using a sodium sulphate solution, or ASTM Soundness Test C88, using a magnesium sulphate solution.
- 10% Fines Value to BS EN 1097-2:1998 or BS 812-111:1990.
- Aggregate Abrasion Value to BS EN 1097-8:2000.

C.3 Stockpile samples shall be examined and tested at frequencies determined by the Engineer.
C.4  The properties of the aggregates shall be such that the Drying Shrinkage of concrete prepared and tested in an approved laboratory in accordance with the United Kingdom Building Research Station Digest No. 35 (Second Series) shall not exceed 0.045 percent. The Initial Drying Shrinkage of all the proposed concrete mixes prepared and tested in an approved laboratory in accordance with BS EN 1367-4: 1988 shall not exceed 0.06 percent.

C.5  Aggregate for use in concrete or mortar that will be subject to wetting, exposure to a humid atmosphere or in contact with moist ground shall also be subject to the following conditions: -

- Aggregate shall not contain material that is deleteriously reactive with the alkalis in the cement or is present in the aggregates and mixing water or water in contact with the concrete, in amounts sufficient to cause excessive localized or general expansion of concrete or mortar.
- Dacite, Andesite, Rhyolites, Opal Cherts or Tuffs shall not be used in aggregates.
- Coarse and fine aggregates shall be tested for reactivity potential and shall satisfy the criteria given for innocuous aggregates in ASTM C 1260. The period of testing shall be a minimum of 26 weeks unless otherwise agreed by the Engineer.

D.  Fine Aggregates

D.1  Fine concrete aggregates shall conform to AASHTO M6 and shall consist of natural sand or crushed rock having hard and durable particles or, if approved by the Engineer, other inert materials having similar characteristics. 100% of the fine aggregate shall pass the 9.5 mm sieve and 2% to 10% shall pass the 0.15 mm sieve. The fine aggregate shall not contain harmful materials including iron pyrites, coal, mica, shale or similar laminated materials, flat or elongated particles or any materials which may adversely affect the reinforcement or the strength, durability and texture of the concrete.

D.2  The Contractor shall wash the fine aggregates to remove deleterious substances or for colour consistency. Washing shall be carried out using fresh water. The water shall be replaced regularly to minimise the chloride and/or sulphate content.

D.3  The total acid soluble sulphate content (BS EN 1744-1:1998 or BS 812-118 1988) of fine aggregate, expressed as sulphur trioxide (SO₃), shall not exceed 0.40% by dry weight (BS EN 1744-1:1998 or BS 812-117:1988). The total acid soluble chloride content, expressed as sodium chloride (NaCl), shall not exceed 0.10% by dry weight of fine aggregate. The following additional requirements shall apply to the concrete mix:

- Total sulphate content (as SO₃) of any mix, excluding that present in the cement but including any present in the other materials, shall not exceed 2.5% by weight of cement in the mix.
- Total chloride content (as NaCl) of any mix, including any chloride present in the other materials and in the mix water, shall not exceed 0.35% by weight of cement in the mix.
D.4 Fine aggregate shall meet the following additional requirements:

- Fineness modulus, AASHTO M6: ±0.20% of approved value which shall be not greater than 3.1 or less than 2.3. Sieve analysis to AASHTO T27.
- Sodium or magnesium sulphate soundness AASHTO T104: max 12%, 18% loss respectively.
- Content of clay lumps and friable particles, AASHTO T112-82: 3% max.
- Sand equivalent AASHTO T176: min 75%.
- Coal and lignite, AASHTO T113-82: 0.5% Max.
- Organic impurities AASHTO T21-81: not darker than standard colour.

D.5 The amount of hollow shells likely to form voids and present in material retained on a 2.36 mm sieve determined by direct visual separation, shall not exceed 3% by weight of the entire sample.

D.6 When sampled and tested in accordance with the appropriate sections of BS 812 (using test sieves in accordance with BS 410-1:2000 and 410-2:2000) the grading of fine aggregates shall be within the limits of the grading zones given in BS-EN 12620:2002. The fine aggregate shall be described as a fine aggregate of the grading zone into which it falls.

D.7 If the fineness modulus varies by more than 0.2 from the value assumed in the concrete mix design, the use of such fine aggregate shall be discontinued until suitable adjustments can be made to the mix proportions to compensate for the difference in gradation.

E. Coarse Aggregates

E.1 Coarse concrete aggregates shall conform to AASHTO M80 and shall consist of gravel, crushed gravel or crushed stone free from coatings of clay or other deleterious substances. It shall not contain harmful materials which can attack the reinforcement or adversely affect the strength and durability of the concrete. Coarse aggregate shall be washed to remove deleterious substances or for consistency of colour in the concrete.

E.2 The total acid soluble sulphate content (BS EN 1744-1: 1998) of coarse aggregate expressed as sulphur trioxide (SO\(_3\)) shall not exceed 0.40% by weight. The total acid soluble chloride contents of coarse aggregates, expressed as sodium chloride (NaCl), shall not exceed 0.05% by weight. These limits are also subject to the following requirements:

- The total sulphate content (as SO\(_3\)) of any mix, excluding that present in the cement but including any present in the other materials, shall not exceed 2.5% by weight of cement in the mix.
- The total chloride content (as NaCl) of any mix, including any chloride present in the other materials and the mix water, shall not exceed 0.35% by weight of cement in the mix.
E.3 Coarse aggregate shall also meet the following requirements:

- Sodium or magnesium sulphate soundness AASHTO T104: 5 cycles: max 12%, 18% loss respectively.
- Abrasion: in accordance with AASHTO T96 Max 40% loss.
- Content of clay lumps and friable particles: AASHTO T112-81: max 1% by weight.
- Soft fragments and shale: AASHTO M80: max 5% by weight.
- Flakiness index: BS EN 933-3: 1997: 30% max.
- Elongation index, BS 812-105.2:1990: 30% max.
- Coal and Lignite: AASHTO T113-82: 0.5% max.

E.4 The grading of coarse aggregate shall comply with AASHTO M43.

E.5 The coarse concrete aggregate, when tested according to AASHTO T27, shall meet the following gradation requirements and shall be graded within the limits stated in Table 5.1.1.

**TABLE 5.1.1: LIMITS OF GRADATION FOR COARSE AGGREGATES**

<table>
<thead>
<tr>
<th>AASHTO Sieve Size</th>
<th>mm</th>
<th>Percent Passing by Weight for</th>
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<td></td>
<td></td>
<td>Grading I</td>
<td>Grading II</td>
<td>Grading III</td>
<td>Grading IV</td>
<td>Grading V</td>
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<tr>
<td>3' 75</td>
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<td>-</td>
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<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
<td>0-1</td>
</tr>
</tbody>
</table>

E.6 The type of grading for coarse concrete aggregates shall depend on the maximum particle size, which shall be no larger than one-fifth (1/5) of the narrowest dimension between sides of forms, nor larger than two-thirds (2/3) of the minimum clear spacing between reinforcing bars, whichever is least.

E.7 Before batching, all types of coarse aggregate shall be separated into fractions having uniform gradings.

F. Combined Aggregates

F.1 Combined aggregate comprises of a mixture of coarse and fine aggregates. They shall be used only in proportions agreed with the Engineer.
F.2 Materials passing the No. 200 (0.075 mm) sieve shall not exceed 3% by weight of the combined aggregate.

F.3 The combined concrete aggregate gradation shall be as specified or as directed by the Engineer. Grading 7 of Table 5.1.2 shall be used for kerbs, handrails, parapets, posts and other similar sections or members with reinforcement spacing too close to permit proper placement and consolidation of the concrete.

F.4 Changes from one gradation to another shall not be made during the progress of work unless approved by the Engineer.

F.5 For the proportion of each fraction of coarse aggregate and for fine and coarse aggregate, the combined gradings in Table 5.1.2 shall be used for the mix proportion design.

**TABLE 5.1.2: LIMITS OF GRADATION FOR COMBINED AGGREGATES**

<table>
<thead>
<tr>
<th>AASHTO Sieve Size</th>
<th>mm</th>
<th>Grading 1</th>
<th>Grading 2</th>
<th>Grading 3</th>
<th>Grading 4</th>
<th>Grading 5</th>
<th>Grading 6</th>
<th>Grading 7</th>
</tr>
</thead>
<tbody>
<tr>
<td>3&quot;</td>
<td>75</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2 1/2&quot;</td>
<td>63</td>
<td>88-95</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2&quot;</td>
<td>50</td>
<td>78-90</td>
<td>88-95</td>
<td>100</td>
<td>100</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1 1/2&quot;</td>
<td>37.5</td>
<td>66-81</td>
<td>74-86</td>
<td>80-92</td>
<td>93-98</td>
<td>100</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1&quot;</td>
<td>25.0</td>
<td>51-70</td>
<td>56-75</td>
<td>63-80</td>
<td>70-88</td>
<td>87-96</td>
<td>100</td>
<td>-</td>
</tr>
<tr>
<td>3/4&quot;</td>
<td>19.0</td>
<td>43-62</td>
<td>47-67</td>
<td>52-72</td>
<td>60-79</td>
<td>73-86</td>
<td>80-96</td>
<td>100</td>
</tr>
<tr>
<td>1/2&quot;</td>
<td>12.5</td>
<td>32-53</td>
<td>36-58</td>
<td>41-60</td>
<td>47-66</td>
<td>57-74</td>
<td>61-80</td>
<td>73-86</td>
</tr>
<tr>
<td>3/8&quot;</td>
<td>9.5</td>
<td>27-48</td>
<td>30-53</td>
<td>36-54</td>
<td>40-60</td>
<td>48-68</td>
<td>52-72</td>
<td>61-79</td>
</tr>
<tr>
<td>No. 4</td>
<td>4.75</td>
<td>19-38</td>
<td>22-42</td>
<td>23-43</td>
<td>28-49</td>
<td>34-55</td>
<td>38-56</td>
<td>43-64</td>
</tr>
<tr>
<td>No. 8</td>
<td>2.36</td>
<td>9-27</td>
<td>10-29</td>
<td>12-30</td>
<td>16-36</td>
<td>24-40</td>
<td>25-41</td>
<td>26-46</td>
</tr>
<tr>
<td>No. 16</td>
<td>1.18</td>
<td>4-19</td>
<td>5-21</td>
<td>6-22</td>
<td>7-25</td>
<td>9-28</td>
<td>11-29</td>
<td>13-33</td>
</tr>
<tr>
<td>No. 30</td>
<td>0.600</td>
<td>3-15</td>
<td>4-17</td>
<td>4-19</td>
<td>5-21</td>
<td>7-23</td>
<td>8-24</td>
<td>10-28</td>
</tr>
<tr>
<td>No. 50</td>
<td>0.300</td>
<td>2-11</td>
<td>2-13</td>
<td>2-14</td>
<td>2-15</td>
<td>4-17</td>
<td>5-19</td>
<td>5-21</td>
</tr>
<tr>
<td>No.100</td>
<td>0.150</td>
<td>1-7</td>
<td>1-8</td>
<td>1-8</td>
<td>1-9</td>
<td>2-10</td>
<td>2-11</td>
<td>2-12</td>
</tr>
<tr>
<td>No.200</td>
<td>0.075</td>
<td>0-3</td>
<td>0-3</td>
<td>0-3</td>
<td>0-3</td>
<td>0-3</td>
<td>0-3</td>
<td>0-3</td>
</tr>
</tbody>
</table>

**G. Site Storage of Aggregates**

G.1 Adequate stocks of tested and approved aggregates shall be maintained on site and the capacity of the storage bins for each type and grading of aggregate shall be sufficient to hold the respective quantities required for the maximum amount of concrete which the Contractor is obliged or intends to pour in any continuous operation in one day. The maximum height of aggregate stockpiles shall be 1.50 metres. Different grades of aggregates shall be separated by concrete block walls.
G.2 Dense concrete or bituminous slabs shall be laid with sufficient falls to cover all aggregate stockpile areas or bins and shall extend to cover all surrounding areas where aggregates are likely to be discharged or handled. These areas shall be swept and kept clean at all times to ensure that the aggregates are not contaminated by the adjacent ground through trafficking or otherwise and shall be constructed with adequate drainage for surplus water.

G.3 Windbreaks shall be provided where aggregates might suffer excessive contamination from windblown materials. During periods of heavy rain the bins or stockpiles shall be covered by tarpaulins.

H. Rejection of Aggregates

H.1 The Engineer shall reject any stockpiled material that has an excess build-up of fines.

H.2 Aggregates suffering from segregation or contamination during processing, handling at source, transportation to the site, stockpiling, handling on site or otherwise not complying with the requirements of the Specification shall be rejected and removed promptly from site regardless of any prior approval of the source.

I. Washing and Processing Aggregate

The Contractor shall carry out on site supplementary processing or effective washing of coarse and fine aggregates as necessary to comply with all requirements of the Specification.

J. Water

J.1 All sources of water, whether for mixing or curing of concrete or compaction of backfill around the concrete structures shall be approved by the Engineer. If during construction water from a particular approved source becomes unsuitable for purpose, the Contractor shall provide satisfactory water from other approved sources.

J.2 Water shall be free from injurious quantities of oil, alkali, vegetable matter and salt. The water shall be reasonably clear and shall contain not more than one quarter (0.25) percent solids by weight. Water shall comply with the requirements of BS EN1008:2002. If the specific conductance is less than 1500 micro ohms per centimetre, the total solids content requirement shall be waived, if agreed with the Engineer.

J.3 Non-potable water shall only be used when potable water is not available and provided the impurities do not exceed the values given in Table 5.1.3.

J.4 The water used in the mix design shall be from a source approved by the Engineer for site use.

J.5 Water used concrete containing or in contact with aluminium fittings or fixtures shall not contain chloride ions.
TABLE 5.1.3: MAXIMUM PERMITTED IMPURITIES IN NON-POTABLE WATER

<table>
<thead>
<tr>
<th>Impurity</th>
<th>Max. Concentration (ppm)</th>
<th>Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chloride as (Cl-)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Prestressed concrete or concrete in bridge decks</td>
<td>500</td>
<td>ASTM D512</td>
</tr>
<tr>
<td>b) Other reinforced concrete</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- in a moist environment, or</td>
<td></td>
<td></td>
</tr>
<tr>
<td>- containing aluminium anchorages or reinforcement, or</td>
<td>1000</td>
<td></td>
</tr>
<tr>
<td>- permanent galvanized metal formwork</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulphates as SO₄</td>
<td>300</td>
<td>ASTM D516</td>
</tr>
<tr>
<td>Alkalis as Na₂O+0.658 K₂O</td>
<td>600</td>
<td>AASHTO T-26</td>
</tr>
<tr>
<td>Total solids</td>
<td>5000</td>
<td></td>
</tr>
</tbody>
</table>

K. Admixtures

K.1 The quantity and method of using admixtures shall be in accordance with the manufacturer's recommendations and in all cases shall be subject to the approval of the Engineer.

K.2 The Contractor shall provide the following information for the Engineer's approval:

- The quantity to be used in kilograms per kilogram of cement and in kilograms per cubic metre of concrete.
- The detrimental effects caused by adding a greater or lesser quantity in kilograms per cubic meter of concrete.
- The chemical name(s) of the main active ingredient(s).
- Whether the admixture leads to the entraining of air.

K.3 The Contractor shall demonstrate the suitability of an admixture by means of trial mixes.

K.4 The use of calcium chloride in any form is prohibited.
L. High Workability Admixtures

L.1 Superplasticising agents shall be used when detailed on the Drawings or directed by the Engineer. The superplasticiser shall be stored and used strictly in accordance with the manufacturer's instructions and shall be fully compatible with all proposed concrete mix constituents. The optimum dosage of the additive shall be determined by site and laboratory trials to the Engineer's approval. The Contractor shall submit to the Engineer full details of his proposed mix design, which shall ensure that the minimum strength requirements as specified for the particular use of the concrete are achieved. Only when the Engineer has approved the proposed mix design shall such a mix be used in the Works.

L.2 The Contractor's mixing and transporting plant shall include accurate metering equipment for the measurement of superplasticising agents so that additives may be introduced immediately before placing.

L.3 The Contractor's rates for concrete listed in the Bill of Quantities shall include for the use of superplasticisers. The rate shall be inclusive for compliance with the Specification together with all necessary testing and trials for concrete containing superplasticisers.

5.01.3 DEFINITIONS

A. Crushing Strength

The crushing strength of a test cylinder prepared in accordance with AASHTO T23 and AASHTO T126 or standard cubes prepared with accordance to BS specifications.

B. Average Strength

The mean of the crushing strengths of specimens taken from a sample of concrete.

C. Characteristic Strength

The value of the crushing strength below which 5% of the population of all possible strength measurements of the specified concrete are expected to fall.

D. Fresh Concrete

Concrete during the first two hours after the addition of water to the mix.

E. Batch

The quantity of concrete mixed in one cycle of operations of a batch mixer, the quantity of concrete conveyed ready-mixed in a vehicle or the quantity discharged during one minute from a continuous mixer.
F. Sample

A quantity of concrete taken from a batch whose properties are to be determined.

G. Regular Sampling

The sampling of concrete nominally of the same mix received regularly from the same source.

H. Specimen

Cylinder or cube taken from a sample for testing.

5.01.4 CONCRETE STRENGTH REQUIREMENTS

A. Design Mixes

A.1 Mixes for the classes of concrete (shown in Table 5.1.4) shall be designed by the Contractor. The quantity of water used shall not exceed that required to produce a concrete with sufficient workability to be placed and compacted in the particular location required. Unless otherwise approved by the Engineer, the mix designs shall use continuously graded aggregates. All mix designs shall be submitted to the Engineer for approval.

A.2 The Cement content in any mix shall not exceed 450 kg/m³.

A.3 The 7-day compressive strength of any mix shall not be less than 75% of the specified 28 day strength. If the 7-day result is below the 75% requirement, the Contractor shall postpone works related to the suspected concrete until the 28 days results are available, unless otherwise agreed to by the Engineer, at the Contractor’s risk.

A.4 The ultimate compressive strength of concrete shall be determined on test specimens obtained as follows:

Either: Test cylinders prepared and tested in accordance with AASHTO T23 and AASHTO T126. Six inch by twelve inch cylinders shall be used for all compression tests.

Or: Cubes prepared and tested in accordance with BS 1881.
TABLE 5.1.4: CONCRETE CLASS AND DESIGN MIXES

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Cylinder Works Strength at 28 days: Kg/cm²</th>
<th>Equivalent Works Cube Strength @ 28 days: Kg/cm²</th>
<th>Maximum Size of Aggregate: mm</th>
<th>Minimum Cement Content Kg/m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>110/25 (Blinding)</td>
<td>110</td>
<td>140</td>
<td>25</td>
<td>220</td>
</tr>
<tr>
<td>140/25</td>
<td>140</td>
<td>180</td>
<td>25</td>
<td>250</td>
</tr>
<tr>
<td>170/60</td>
<td>170</td>
<td>210</td>
<td>60</td>
<td>275</td>
</tr>
<tr>
<td>210/50</td>
<td>210</td>
<td>260</td>
<td>50</td>
<td>300</td>
</tr>
<tr>
<td>210/25</td>
<td>210</td>
<td>260</td>
<td>25</td>
<td>325</td>
</tr>
<tr>
<td>210/20 (B20)</td>
<td>210</td>
<td>260</td>
<td>20</td>
<td>325</td>
</tr>
<tr>
<td>250/20 (B25)</td>
<td>250</td>
<td>310</td>
<td>20</td>
<td>350</td>
</tr>
<tr>
<td>250/30</td>
<td>250</td>
<td>310</td>
<td>30</td>
<td>350</td>
</tr>
<tr>
<td>310/20</td>
<td>310</td>
<td>385</td>
<td>20</td>
<td>375</td>
</tr>
<tr>
<td>360/20</td>
<td>360</td>
<td>450</td>
<td>20</td>
<td>425</td>
</tr>
<tr>
<td>400/20</td>
<td>400</td>
<td>500</td>
<td>20</td>
<td>425</td>
</tr>
<tr>
<td>500/20</td>
<td>500</td>
<td>625</td>
<td>20</td>
<td>425</td>
</tr>
<tr>
<td>600/20</td>
<td>600</td>
<td>750</td>
<td>20</td>
<td>425</td>
</tr>
</tbody>
</table>

B. Nominal Concrete Mix

B.1 General

Concrete for use as backfilling for structural excavation shall be either no-fines concrete or cyclopean concrete as directed by the Engineer. The cement: aggregate ratio of such mixes shall be not greater than 1:15 and the minimum cylinder strength at 28 days shall be not less than 50 Kg/cm² or minimum 28-day cube strength shall no be less than 60 Kg/cm².

B.2 No-Fines Concrete

No-fines concrete shall comply with the grading in Table 5.1.5 and shall be mixed and laid in general conformity with this Section 5.01.

B.3 Cyclopean Concrete

Plums used in cyclopean concrete shall consist of non-reactive broken stone spalls or boulders ranging in size from 200mm to 300mm. They shall be free from sharp or angular edges and shall not form more than 30% of the total volume of concrete. They shall be evenly graded and shall be soaked in water prior to incorporation in the mix. Plums shall be evenly distributed in the concrete mix with a minimum cover of 100mm. The compressive strength the rock plums shall be at least 100 Kg / cm² to ASTM D2938. The concrete used in cyclopean concrete shall be Class B20
TABLE 5.1.5:  GRADING FOR NO-FINES CONCRETE

<table>
<thead>
<tr>
<th>Sieve Size</th>
<th>% by Dry Weight Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>90 mm</td>
<td>100</td>
</tr>
<tr>
<td>40 mm</td>
<td>85-100</td>
</tr>
<tr>
<td>20 mm</td>
<td>0 - 20</td>
</tr>
<tr>
<td>10 mm</td>
<td>0 - 5</td>
</tr>
</tbody>
</table>

C. Compliance with Strength Requirements

C.1 General. Cylinders or cubes from concrete as mixed for the Work will be tested in accordance with AASHTO T22 or BS 1881, as appropriate, after both seven and twenty eight days. Test specimens shall be made and cured in accordance with AASHTO T23 or BS 1881. These specimens will be the basis for acceptance of the concrete in the structure.

C.2 Preliminary Tests

C.2.1 Prior to the commencement of any concreting work and subsequently, whenever a change in the mix is intended, preliminary tests shall be carried out. From each of three samples of materials, a trial mix shall be made. For each class of concrete, the trial mixes shall represent at least two different water-cement ratios. From each trial mix, six cylinders (or cubes) shall be made, three for testing at 7 days, and three for testing at 28 days. The average strength of the cylinders (or cubes) tested for each sample shall be taken as the preliminary cylinder (or cube) strength of the mix.

C.2.2 The Engineer will require the preliminary test to be repeated if the difference in strength between the greatest and the least strength is more than 20 per cent of the average.

C.2.3 The water/cement ratio and slump adopted in the preliminary tests for each class of concrete shall be used in the works concrete. It shall be such that, if selected for use at the Site, the concrete can be worked readily into the corners and angles of the forms and around the reinforcement without permitting the materials to segregate or free water to collect on the surface.

C.2.4 Preliminary tests shall have these minimum ultimate strengths given in Table 5.1.6.
C.3 Works Tests

C.3.1 During the first four days of the commencement of concreting with any particular mix, two sets of six works cylinders (or cubes) in each set shall be made each day. Three cylinders (or cubes) from each set shall be tested at 7 days, and 3 at 28 days. The above works tests shall be carried out for each class of concrete. Subsequently, the frequency of making sets of test cylinders (or cubes) and the number in each shall be as directed by the Engineer.

### TABLE 5.1.6: PRELIMINARY TESTS FOR STRENGTH

<table>
<thead>
<tr>
<th>Class of Concrete</th>
<th>Cylinder Strength (Kg/cm²)</th>
<th>Equivalent Cube Strength (Kg/cm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110/25</td>
<td>170</td>
<td>210</td>
</tr>
<tr>
<td>140/25</td>
<td>210</td>
<td>260</td>
</tr>
<tr>
<td>170/60</td>
<td>240</td>
<td>300</td>
</tr>
<tr>
<td>210/50</td>
<td>290</td>
<td>360</td>
</tr>
<tr>
<td>210/25</td>
<td>290</td>
<td>360</td>
</tr>
<tr>
<td>210/20</td>
<td>290</td>
<td>360</td>
</tr>
<tr>
<td>250/20</td>
<td>325</td>
<td>400</td>
</tr>
<tr>
<td>250/30</td>
<td>325</td>
<td>400</td>
</tr>
<tr>
<td>270/20</td>
<td>350</td>
<td>430</td>
</tr>
<tr>
<td>310/20</td>
<td>395</td>
<td>490</td>
</tr>
<tr>
<td>360/20</td>
<td>440</td>
<td>550</td>
</tr>
<tr>
<td>400/20</td>
<td>480</td>
<td>600</td>
</tr>
<tr>
<td>450/20</td>
<td>520</td>
<td>650</td>
</tr>
</tbody>
</table>

C.3.2 The cylinders (or cubes) shall be cured in the same conditions and environment as the members they represent. The cylinder (or cube) strength shall be accepted as complying with the specified requirement for work cylinder (or cube) strength if none of the compressive strengths of the cylinders (or cubes) falls below the minimum strengths given in Table 5.1.4 or if the average strength is not less than the specified minimum works cylinder (or cube) strength and the difference between the greatest and least cylinder (or cube) strength is not more than 20 per cent of the average.

C.3.3 For the concrete batch to be accepted, not more than 5 per cent of works cylinder (or cube) strengths shall fall below the specified strength. For this requirement to be achieved, the mean strengths of works cylinders (or cubes) less 1.64 times the standard deviation should not be less than the required strength. This calculation shall be made for both 7 and 28 day cylinder (or cube) tests as soon as 24 cylinders (or cubes) have been tested at each age. Thereafter, it shall be repeated as further test results become available at a frequency determined by the Engineer. The number of cylinders (or cubes) considered in each calculation shall be the total number of cylinders (or cubes) of the mix in question tested from the commencement of the Works.
C.3.4 Cores shall be taken in accordance with ACI 318 and tested in accordance with AASHTO T24. Load testing shall be carried out in accordance with ACI 318, chapter 20. The Contractor shall hire an authorized independent laboratory to carry out such tests at his own expense.

C.4 The Engineer shall instruct the preparation of additional test cylinders or cubes if necessary to ascertain the effectiveness of the methods by which the structure is being cured and also to determine when the structure may be placed in service. These cylinders or cubes shall be cured in the field in the same manner as the concrete placed in the structure, and the Contractor shall protect the cylinders or cubes from all damage.

C.5 The Contractor shall take every precaution to prevent damage to the test cylinders or cubes during handling, transporting and storing. He shall be held solely responsible for any test failure caused by improper handling, transportation or any other cause which may be detrimental to the test cylinder or cube.

C.6 In order that the test cylinders or cubes are transported from the field to the laboratory undamaged, the Contractor shall provide a minimum of two approved boxes (one for the Contractor's use and the other for the Engineer's use). Boxes shall be of such size to receive a minimum of six test cylinders or cubes and sufficient space for sawdust packing around all surfaces of the cylinders or cubes. Boxes shall be approved by the Engineer. The Contractor shall, when directed by the Engineer, provide as many additional boxes as may be required by the remoteness and/or magnitude of the concrete work.

C.7 When test cylinders or cubes fail to meet the minimum strength requirements, the Engineer shall instruct core samples to be taken to determine the acceptability of structural elements. The Contractor shall, at his own expense, furnish all equipment required for such core sampling.

5.01.5 COMPOSITION OF CONCRETE

A. Mix Proportions

A.1 The Contractor shall consult with the Engineer on mix proportions at least forty-five (45) days prior to the commencement of concrete work. The actual mix proportions of cement, aggregates, and water shall be determined by the Contractor.

A.2 The Contractor shall, in the presence of the Engineer, prepare trial-mixes for each class of concrete required for the project, made with the approved materials to be used in the Works. The proportions of the trial-mixes shall be such as to produce a dense mixture containing the specified minimum cement content and meeting the workability and the preliminary test strength requirements specified for the designated class of concrete.
A.3 If the materials supplied by the Contractor are of such a nature or are so graded that proportions based on minimum cement content cannot be used without exceeding the maximum allowable water content, the use of admixtures to maintain the water content within the specified limit shall be permitted, subject to the approval of the Engineer. At all times the concrete mix shall satisfy the durability requirements by satisfying the minimum and maximum specified cement and water contents.

A.4 The Engineer shall review the Contractor's trial-mixes against the seven and twenty eight day test cylinder or cube strength results and determine which of the trial-mixes shall be used. If none of the trial-mixes for a particular class of concrete meets the specification, the Engineer shall direct the Contractor to prepare additional trial-mixes. No class of concrete shall be prepared or placed until its job-mix proportions have been approved by the Engineer.

A.5 The approval of the job-mix proportions by the Engineer or his assistance to the Contractor in establishing those proportions, does not relieve the Contractor of the responsibility of producing concrete which meets the specified requirements.

A.6 All costs connected with the preparation of trial-mixes and the design of the job-mixes shall be borne by the Contractor.

B. Design Limits

The following parameters shall be designated by the Engineer within the limits of the specifications:

- The minimum cement content in sacks per cubic metre of concrete.
- The maximum allowable water content in litres per sack of cement, or equivalent units, including surface moisture, but excluding water absorbed by the aggregates.
- The ratio of coarse and fine aggregates.
- Slump or slumps designated at the point of delivery.

C. Changes to Mix Design

C.1 Changes in mix proportions requested by the Contractor to previously approved mix designs shall only be made following approval by the Engineer.

C.2 If, in the opinion of the Engineer, cement is being lost due to windy conditions, the Contractor shall add additional amounts of cement as directed by the Engineer. No additional payment shall be made for the additional cement.

C.3 The Engineer shall instruct the Contractor to change the proportions of any particular mix if conditions warrant such changes to produce satisfactory results. Any such change shall be made within the limits of the specifications at no additional cost to the Contract.
C.4 When, in the opinion of the Engineer, additional protection against concrete deterioration due to a salty environment is necessary, he shall instruct the Contractor to increase the cement content of a particular mix by ten per cent over and above that cement content used in the approved trial-mix design for a non-salty environment, irrespective of the use of water barriers. The water content shall be adjusted accordingly to obtain a dense workable mix. All bridge footings and column lengths to the first construction joint above the ground surface for the entire project are subject to this increased cement content. No additional payment shall be made for the increase in cement content.

C.5 Failure of the mix to meet specifications determined by the Engineer under items A and B in this sub-section will be grounds for the Engineer to reject the concrete.

C.6 Mortar for laying stone for grouted stone riprap, grouted stone wash checks or grouted stone ditch lining shall be composed of one part of Ordinary Portland Cement and three parts of fine aggregate by volume with water added to make a workable mix. The amount of water added to the mix shall be approved by the Engineer.

C.7 Aggregates for masonry mortar shall conform to AASHTO M45.

C.8 Portland cement shall conform to AASHTO M85, Type I, II or III.

5.01.6 REQUIREMENTS FOR COMBINING MATERIALS

A. Measurement of Materials in Mix

A.1 Cement shall be measured in bulk or as packed by the manufacturer (in 50 kilogram sacks). Measurement shall be accurate to within (+/-) 3.0 %.

A.2 Water: The mixing water shall be measured by weight or by volume. In either case the measurement shall be accurate to within (+/-) 2.0 %.

A.3 Aggregates: The aggregates shall be measured by weight. The measurement shall be accurate to within (+/-) 2.0% for fine and coarse aggregates.

A.4 Additives: Additives shall be measured by volume if in liquid form and by weights if solid. The measurement shall be accurate to within (+/-) 3.0 %.

B. Assembly and Handling of Materials

B.1 Assembly: Aggregates shall be delivered and stored in such quantities that sufficient material approved by the Engineer is available to complete any continuous pour necessary for structures. The batching site shall be of adequate size to permit the stockpiling of sufficient unsegregated material of uniform moisture content to ensure continuous operation. The Contractor shall take measures to ensure that no foreign matter or materials capable of changing the desired proportions are included in the mix. If two or more sizes or types of coarse or fine aggregates are used on the same Project, only one size or type of each aggregate may be used on a continuous pour.
B.2 **Stockpiling of Aggregates:** All aggregates shall be stockpiled before use in order to prevent segregation of material, to ensure a uniform moisture content and to provide uniform conditions for proportioning plant control. The use of equipment or methods of handling aggregates which results in the degradation or segregation of the aggregates is strictly prohibited. Bulldozers with metal tracks shall not be used on coarse aggregate stockpiles and all equipment used for handling aggregates shall be approved by the Engineer. Methods of stockpiling aggregates shall be approved by the Engineer. Segregation shall be prevented by making no layer higher than 1.5 metres and, if two or more layers are required, each successive layer shall not be allowed to "cone" down over the next lower layer. Aggregates shall not be stockpiled against the supports of proportioning hoppers or weighing devices.

B.3 **Segregation:** Segregated aggregates shall not be used until they have been thoroughly remixed and the resultant pile is of uniform gradation at any point from which a representative sample is taken. The Contractor shall remix aggregate piles when so ordered by the Engineer.

B.4 **Transporting of Aggregates:** If aggregates are to be transported from a central proportioning plant to the mixer in batch-boxes or dump trucks, such equipment shall be of sufficient capacity to carry the full volume of materials for each batch of concrete. Partitions separating batches shall be approved by the Engineer and shall be adequate and effective to prevent spilling from one compartment to another while in transit or being deposited.

B.5 **Storage of Cement:** Cement may be stored in securely locked dry places either in bulk (unpacked) or in bags.

   a) All cement bags shall be marked with the date of manufacture and with the date of storage so that they can be taken out for use in the same order as they were brought in to storage.

   b) Cement bags shall be placed on wooden shelves at least 100 mm above ground and 150 mm clear of walls.

   c) Unpacked cement shall not be used six months after manufacture and bagged cement three months after manufacture unless it has been retested in accordance with 5.01.02 A13.

   d) No cement shall be used which has been affected by humidity regardless of the date of manufacture.

   e) Cement shall be transported to the mixer in the original sacks. Each batch shall contain the full amount of cement for the batch. Batches where cement is placed in contact with the aggregates may be rejected unless mixed within 1.5 hours.
C. Mixing

Concrete shall be mixed in the quantities required for immediate use. Concrete shall not be used which has developed initial set. Retempering concrete by adding water or by other means shall not be permitted. Concrete that is not within the specified slump limits at the time of placement shall not be used and shall be disposed of as directed by the Engineer.

C.1 If washed sand is used while still wet the mixing time starts with the addition of cement to the aggregate, even if the water required for the mixing has not been added.

C.2 The concrete shall be mixed at the site of the Works, in a central-mix plant, or in truck mixers. The mixer shall be of a type and capacity approved by the Engineer. Ready-mixed concrete shall be mixed and delivered in accordance with the requirements of Sub-Section 5.01.7 "Ready-Mixed Concrete and Central-Mixed Concrete".

C.3 The coarse aggregate shall first be loaded into the mixer followed by the fine aggregate. Some mix water shall be added to the mix before the cement is loaded into the mixer. Water shall be continuously added throughout mixing. Additives, if required and approved by the Engineer, shall be added according to the manufacturer’s instructions. Retarders shall be added within one minute or 25% of the total mixing time whichever is the smaller.

C.4 The manufacturer’s instructions shall be followed in respect of overloading the mixer and the selection of the rate of revolution of the mixers.

C.5 To avoid segregation in the fresh concrete, the free drop height on emptying the mixer shall be not greater than 1.5 metres.

C.6 After mixing, the concrete shall be homogeneous and comply with the provisions of these specifications. The Engineer shall, if the mix fails to produce concrete of the required strength, vary the mix time.

D. Central Mixing

Plants for concrete shall comply with the following requirements, in addition to those set forth above:

D.1 Cement: The provisions for storing cement shall be approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of previous cement batches before starting to manufacture concrete for the Works.

D.2 Aggregate: Coarse and fine aggregate to be used in concrete shall be kept in stockpiles and bins apart from aggregate used in other work. Aggregate shall be provided from a source approved by the Engineer. The Contractor shall clean all conveyors, bins and hoppers of previous aggregate batches before starting to manufacture concrete for the Works.

D.3 Consistency: The Contractor shall be responsible for producing concrete that is homogeneous and complies with the provisions of these specifications.
D.4 **Hauling:** Mixed concrete from the central-mixing plant shall be transported in truck mixers, truck agitators or non-agitating trucks having special bodies or other approved containers.

D.5 **Time of Haul:** The time elapsing from the time water is added to the mix until the concrete is deposited in place shall be not greater than the following:

- Thirty minutes when the air temperature is 25°C or higher.
- Forty minutes when the air temperature is 18°C or below.
- Interpolated time when the air temperature is between 18°C and 25°C.

For concrete produced on site and transported by means other than transit mixers or agitated trucks.

The maximum haul time may be reduced at the Engineer's discretion if the slump changes or there are signs of the concrete beginning to dry.

D.6 **Delivery:** When supplying concrete from a central plant, the Contractor shall have sufficient plant capacity and transporting equipment to ensure continuous delivery at the rate required. The rate of delivery of concrete during concreting operations shall be regulated to provide for proper handling, placing and finishing of the concrete and the method of delivery and handling the concrete shall be organised to facilitate placing with a minimum of rehandling and avoidance of damage to the structure or the concrete. Methods of delivery and handling for each site shall be approved by the Engineer. The Engineer shall delay or suspend the mixing and placing of concrete at any site, for which he considers the Contractor's delivery equipment inadequate, until such time as the Contractor provides additional approved delivery equipment.

**5.01.7 READY-MIXED AND CENTRALLY-MIXED CONCRETE**

A. **General**

A.1 Ready-Mixed Concrete and Centrally-Mixed Concrete shall consist of a mixture of cement, water and aggregate, without air entrainment or water-reducing admixture. Air-entrainment, water-reduction or other type of admixture shall only be used at the Engineer's discretion. The terms ready-mixed or central-mixed concrete shall include transit-mixed concrete and will be referred to hereinafter as ready-mixed concrete.

A.2 Ready-mixed concrete shall only be used in construction of the Works with the Engineer’s approval.

A.3 Approval of any ready mixed concrete plant will be granted only when an inspection of the plant indicates that the equipment, the method of storing and handling
the materials, the production procedures, the transportation and rate of delivery of concrete from the plant to the point of use, all meet the requirements set forth herein.

A.4 Ready-mixed concrete shall be mixed and delivered to the point of use by means of one of the following combinations of operations:

a) Mixed completely in a stationary central mixing plant and the mixed concrete transported to the point of use in a truck mixer or tank agitator operating at agitator speed, or when approved by the Engineer, in non-agitating equipment (centrally-mixed concrete).

b) Mixed completely in a truck mixer at the batching plant or while in transit (transit-mixed concrete).

c) Mixed completely in a truck mixer at the point of use following the addition of mixing water (truck-mixed concrete).

A.5 Permission to use ready-mixed concrete from any previously approved plant shall be rescinded upon failure to comply with the requirements of the Specification.

B. Materials

All materials used in the manufacture of ready-mixed concrete shall conform to the requirements of Sub-Section 5.01.2: Materials.

C. Equipment

Equipment shall be efficient, well maintained and of the type and number as outlined in the Contractor's Programme of Work. Transit mixers and agitator trucks shall comply with the standards specified in ASTM C94. Non-agitating equipment used for transporting concrete shall be watertight and equipped with gates permitting controlled discharge of concrete and fitted with covers for protection against the weather.

D. Supply

D.1 Where transit mixers are used, the constituent materials shall be mixed dry in the mixer and water added directly before the pour and mixed at the speed and number of turns in accordance with the manufacturer’s recommendations.

D.2 Where concrete is mixed at a central plant, on or off site, the concrete shall be supplied to the pouring area by agitator trucks or transit mixers which rotate at the speed specified by the manufacturers. Non-agitating trucks shall only be permitted if the central plant is on site.

D.3 The time of haul shall not exceed the maximum stated in sub-item D.5 of subsection 5.01.6 of the Specification.
E. Uniformity Tests

Four samples of fresh concrete shall be taken, two after 15% of discharge from the truck mixer or agitator truck and two after 85% discharge and within 20 minutes. Slump and compaction factor tests shall be carried out including any other tests specified or required by the Engineer.

F. Samples

F.1 Samples for strength test shall be taken as specified in Clause C of subsection 5.01.4 of the Specification.

F.2 At least six specimens shall be prepared per sample. Three of these shall be tested at 7 days and three at 28 days.

G. Control of Delivery

G.1 Drivers of delivery trucks shall be provided with trip tickets, which shall be signed by a responsible member of the central plant staff, for submission to the Engineer. The ticket shall contain the following information:
   - Name and address of the Central Plant.
   - Serial number of the ticket and date.
   - Truck number.
   - Class and/or strength of concrete.
   - Cement content of the mix.
   - Loading time.
   - Slump
   - Any other relevant information.

G.2 The Engineer shall send representatives to the central plant at any time to:
   - Check the batching and mixing.
   - Verify loading time.
   - Take a copy of the trip ticket.

G.3 The Contractor and/or concrete supplier shall afford the Engineer and/or his representative, without charge, all facilities necessary to take samples, conduct tests and inspect the central plant to determine whether the concrete is being furnished in accordance with the Specification.

G.4 Concrete delivered in outdoor temperatures lower than 5 °C, or if the temperature is expected to drop below 5 °C during the curing period, shall arrive at the Works having a temperature of not less than 10 °C nor greater than 32 °C.
G.5 In supplying ready-mixed concrete, the plant shall have sufficient batching and transporting capacity to ensure continuous delivery at the rate required. The rate of delivery of concrete during concreting operations shall be sufficient for the proper handling, placing and finishing of concrete. If the rate of delivery is not sufficient for a continuous concrete operation, the Engineer shall suspend all or parts of further concrete work until such time as the Contractor provides adequate additional delivery equipment which, in the opinion of the Engineer, provides a continuous concrete operation.

5.01.8 MEASUREMENT

A. Scope

Concrete works to be measured for payment under Section 5.01 include mass, reinforced and prestressed concrete of both in-situ and precast construction of a general nature but do not include specific components of highway structures, such as concrete piles, concrete parapets and safety barriers, precast concrete kerbs and tiles etc., which are separately described in other sections of the Specification.

B. Measurement

B.1 Concrete shall be measured by the cubic metre in place and accepted by the Engineer, based on the dimensions shown on the Drawings or as otherwise directed by the Engineer.

B.2 Different classes of concrete shall be measured separately.

B.3 Concrete formed by different types of formwork and/or falsework shall be measured separately.

B.4 Concrete of the same class requiring the same formwork but different class of surface finish shall be measured separately.

B.5 Voids, openings or gaps whose size is 0.05 cubic metres or more shall be measured and deducted from the volume of concrete in which they occur.

B.6 All service ducts, irrespective of diameter, shall be measured and deducted from the volume of concrete in which they are located.

B.7 The following deductions in the measurement of the volume of concrete shall not be made:

- Reinforcing bars
- Prestressing ducts, anchors, cones, couplers and grouting tubes
- Embedded metals (bolts, nuts, anchorages, hooks etc)
- Rock plums
- Holes introduced by the Contractor for the convenience of transportation, erection or construction shall not be measured for deduction irrespective of the size of the holes and whether or not the holes are made good.

**B.8** Additional concrete placed by the Contractor for the purpose of facilitating his work shall not be measured for payment.

**C. Item Coverage**

The Contract price paid per cubic metre for concrete shall include full rates for furnishing all labour, materials, tools, equipment and incidentals including, but not limited to, the following:

- Cement, aggregates, water and additives, admixtures and air entraining agents including their testing, storage, handling and transportation.
- Washing of aggregates, if required.
- Ice, if required, added in the mix water.
- Plant, machinery and equipment required for the production of concrete.
- Design of mixes, taking samples and testing specimens.
- Transportation and delivery of concrete to work areas.
- Placing, vibrating and finishing of concrete.
- All formwork irrespective of the material used and the quality of surface finish specified.
- All falsework supporting and stabilising formwork.
- Curing of concrete.
- Tooling, if required, to achieve the specified surface finish.
- Corrective measures and the means of carrying them out required in the event of the concrete being not in accordance with the Drawings and/or specification.
- Handling, transportation and erection of precast concrete members.
- Grout and/or epoxy used in precast construction including material and equipment for temporary prestress, if required.
- Material, plant and equipment associated with particular methods of construction.
- Joint fillers, joint sealants, weep holes, water stops, dowel bars as shown on the drawings including material, plant handling, transportation testing, storage, workmanship and associated accessories.

<table>
<thead>
<tr>
<th>PAY ITEM</th>
<th>UNIT OF MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5.01.1)</td>
<td>Concrete (<em>Specify type, class and finish</em>) Cubic Metre (m³)</td>
</tr>
</tbody>
</table>
SECTION 5.02: CONCRETE HANDLING, PLACING AND CURING

5.02.1 SCOPE

The work covered in this Section consists of the placing, compacting and curing of concrete for mass concrete, reinforced concrete and prestressed concrete structures.

5.02.2 MATERIALS

All concrete materials shall comply with Specification section 5.01: Concrete Mixes and Testing.

5.02.3 PLACING

A. General

A.1 Before preparing and placing any concrete, the Contractor shall submit a work plan to the Engineer for approval, specifying the characteristics of the concrete to be employed, the time at which placing is to start the methodology and the duration. The Engineer's approval at least 24 hours in advance of each placing is required.

A.2 The method and sequence of pour, the equipment to be used, the method of compaction and curing procedures shall be approved by the Engineer, prior to any concrete pour.

A.3 In order to allow satisfactory vibration, the concrete shall be placed in horizontal layers, no thicker than fifty centimetres.

A.4 If the concrete is placed in successive phases, there shall be no separation, discontinuity or difference in appearance between the two successive placings. Before each successive placing, the surface of the in-place concrete shall be carefully roughened, cleaned, washed free of loose particles and dampened.

A.5 Concrete shall be placed so that it shall be undisturbed once trowelled. Slabs shall be poured by starting placement of concrete at the location furthest away from the access point to minimise disturbance by workers or equipment.

A.6 Concrete placed in upright reinforced concrete structures shall either be completed or interrupted for a period of twenty-four hours to avoid the risk of the placed concrete debonding from the reinforcing bars during setting and the initial phase of hardening.
A.7 The temperature of the concrete being placed shall be of the same magnitude as that of the reinforcing bars to avoid poor adhesion. The reinforcing bars shall be protected from the sun or cooled by water jets prior to the placing of the concrete or the pouring shall start during the cooler hours of the day and be suspended when the temperature rises above 33°C, unless otherwise agreed with the Engineer.

A.8 The free-drop height of concrete shall be not greater than 1.5m and the method of placing shall suit the conditions and prevent segregation.

A.9 Placing of concrete shall be continuous between predetermined points such as construction joints, contraction joints and expansion joints.

A.10 Concrete shall be placed to avoid segregation of the materials and displacement of the reinforcement. Concrete shall not be deposited in large quantities at any point and then run or worked along the forms, causing potential segregation of materials.

A.11 The concrete shall be deposited between the forms in horizontal layers and the work shall be carried out continuously between predetermined planes agreed upon by the Contractor and the Engineer.

A.12 The slopes of chutes, where used, shall be not greater than 1 vertical to 2 horizontal or smaller than 1 vertical to 3 horizontal. The slope of the chute shall be constant along its length. The capacity of the chute shall be adequate to deliver the required volume of concrete at the required rate.

A.13 Aluminium pipes shall not be used for delivering concrete. The internal diameter of delivery pipes, if used, shall be not less than 8 times the maximum aggregate size. At the point of delivery, pipes shall be vertical.

A.14 Where buckets and hoppers are used for delivery of concrete, the discharge opening shall be not less than 5 times the maximum aggregate size. The sides of hoppers shall be sloped at not less than 60 degrees to the horizontal.

A.15 When buggies are used to transport fresh concrete, they shall be run on level tracks, which are securely fixed. The buggies shall be run smoothly without sudden jerks and the distance travelled shall be not greater than 60 metres.

A.16 All chutes, buckets, hoppers, buggies and pipes shall be kept clean and free from coatings of hardened concrete by thorough flushing with water after each pour. The water used for flushing shall be discharged clear of the concrete already in place.

A.17 The external surface of all concrete shall be thoroughly worked during the placing using appropriate tools. The method of working shall force all coarse aggregate from the surface and bring mortar against the forms to produce a smooth finish, substantially free from water and air pockets and honeycombing.

A.18 Concrete shall be deposited in water only with the permission of the Engineer and under his supervision. The minimum cement content of the class of
concrete being deposited in water shall be increased 10 per cent without further compensation and the slump shall be approximately 15 centimetres.

A.19 When depositing in water, the concrete shall be carefully placed in the space in which it is to remain in a compact mass, using a tremie, bottom-dumping bucket or other method approved by the Engineer 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 running water. Forms that are not reasonably watertight shall not be used for holding concrete deposited under water.

A.20 When casing is used in drilled shafts, the casing shall be smooth and properly oiled in accordance with the manufacturer’s recommendations and shall extend sufficiently above the grade of the finish shaft to provide excess concrete to compensate for the anticipated slump due to the casing removal. The concrete placed in the casing shall have such a slump and be of such workability that vibration of the concrete is not required.

A.21 No concrete work shall be stopped or discontinued within 45 centimetres of the top of any finished surface unless such work is to be finished with a coping having a thickness of less than 45 centimetres. In this case the joint shall be made at the underside of the coping.

A.22 Concrete in slab spans shall be placed in one continuous operation for each span, unless otherwise shown on the Drawings or directed by the Engineer.

A.23 Concrete in in-situ beam and slab construction shall be placed in one continuous operation, unless otherwise shown on the Drawings or approved by the Engineer. If concrete is to be placed in two separate operations, each placement shall be continuous; first, to the top of the girder stems, and second, to completion. Where a construction joint is permitted between the girder stem and the roadway slab, shop drawings including complete details of key or other methods of bonding shall be prepared by the Contractor and submitted to the Engineer for approval. When such a joint is permitted, deck concrete shall not be placed until the concrete in the girder stem has hardened sufficiently so as not to be damaged by the concreting operations of the deck pour.

A.24 Concrete in arch rings shall be placed so that the cantering is loaded uniformly. Arch rings shall be divided into sections such that each section can be cast for the full cross-section in one continuous operation. The arrangement of the section and the sequence of placing shall be as approved by the Engineer and shall avoid the creation of initial stress in the reinforcement. The section shall be bonded together by suitable keys or dowels. When permitted by the Engineer, arch rings shall be cast in a single continuous operation.

A.25 The method used for transporting concrete batches, materials or equipment over previously placed floor slabs or floor units or over units of structures of continuous design types shall be subject to approval by the Engineer. Trucks, heavy equipment and heavy concentrations of materials are prohibited on floor slabs until the concrete has attained its design strength.
B. Pumping

B.1 The use of pumps shall be permitted only after they have been checked and approved by the Engineer. Only low pressure piston type pumps, working with a water/cement ratio of not more than sixty five hundredths (0.65), shall be permitted. The use of superplastizisers to facilitate pumping for low water/cement ratios shall be permitted, subject to Engineer's review and approval.

B.2 The use of high pressure pumps for pumping concrete is not permitted.

B.3 The mix design shall be checked and approved by the Engineer for suitability for pumping and the concrete shall be tested regularly during pumping for its uniformity and fitness for purpose. If changes to slump, water-cement ratio, consistency or any other characteristics occur, corrective measures shall immediately be taken to ensure that concrete delivered by the pump complies with the requirements of the Specification. Samples shall be taken at the discharge from the mixer/agitator trucks, from the pumps and at the discharge from the pumps.

B.4 The internal diameter of pump delivery pipes shall be not less than three times the maximum aggregate size. The pipes shall not rest on any part of the formwork and shall be supported independently and securely and be readily accessible so that sections can easily be detached to remove any blockage.

B.5 Before approving the use of a pump, the Engineer shall verify that the Contractor has sufficiently resources in the concrete placing team and the necessary equipment for placing and vibrating the concrete.

B.6 The placing of pumps within the forms while concrete is being placed shall not be permitted. When flood prevention is necessary, a seal of concrete shall be placed through a closed chute or tremie and allowed to set to form a barrier.

5.02.4 Compaction

A. General

A.1 The vibration of the concrete shall be considered completed when a thin layer of cement grout appears on the surface and when no more air bubbles, indicating the presence of voids within the concrete, appear on the surface. Vibration shall be limited to prevent segregation.

A.2 Vibration shall be carried out by one of the following methods:
- Internal
- External
- Mixed.
A.3 Vibration shall be carried out in accordance with the guidelines as given in Standard Practice for Consolidation of Concrete (ACI 309) of Part 2 Concrete Practices and Inspection, Pavements, of ACI Manual of Concrete Practice 1988 issued by American Concrete Institute (ACI), unless otherwise directed by the Engineer.

A.4 Internal Vibration shall be executed in all sections which are sufficiently large to permit the insertion and manipulation of immersion vibrators, previously approved by the Engineer and in accordance with the following recommended practices:

- The concrete shall be placed in horizontal layers no thicker than fifty centimetres.
- The vibrator shall be inserted vertically into the concrete to its full length to reach the bottom of the freshly placed layer.
- The distance between two successive insertions shall not exceed five times the diameter of the vibrator itself.
- The vibrator shall not rest on or against either the formwork or the main reinforcing bars.

A.5 External Form Vibrators shall be used for external vibration when it is impossible to use internal vibrators (heavily reinforced thin walls, pipes or other precast, small cross-section element, etc). The water/cement ratio shall be low (0.30 - 0.40) in order to avoid segregation of the concrete, to provide rapid hardening and for the early removal of formwork.

A.6 Mixed Vibration shall be used in the construction of reinforced or prestressed concrete beams. External wall vibrators shall also be used, mounted on the outside of the formwork after this has been suitably reinforced with ribs of U-bars. The mounting of the wall vibrators shall be welded to this reinforcement. Mountings shall be symmetrically positioned on each side of the beam to produce a rotary movement within the concrete during vibration from the bottom towards the top and from the part placed first towards the part placed last.

A.7 Only vibrators in the zone of the formwork with newly placed concrete shall be used. As the casting of the beam advances, the vibrators shall be dismounted and remounted as necessary.

A.8 Elastic supports shall be provided both under the bottom of the beam and in alignment with the braces or tie rods of the formwork walls.

A.9 The network of reinforcing bars and tensioning cables shall not move as a result of the vibration. Special ties (passing through the formwork walls) or spacers shall be used.
A.10 The Contractor shall submit to the Engineer a method statement for approval of his vibration proposals prior to carrying out the work, giving the following details:

- The position of the external wall vibrators.
- The power, frequency and amplitude of the external wall vibrators.
- The number of wall vibrators that will be utilized at the same time.
- The number and type (frequency and size) of the internal vibrators to be used for the consolidation of the concrete.
- The position of the spacers, or the number of ties, to be used to ensure that the reinforcing bar network and the tensioning cables (if any) do not move during vibration.
- The method of placement of concrete and the length of time this operation is expected to take.

A.11 When required, vibration shall be supplemented by hand spading with suitable tools to assure proper and adequate compaction.

B. Poker Vibrators

B.1 The type and size of poker vibrators shall suit the pour size, density of reinforcement and member dimensions. Unless otherwise authorized by the Engineer, the vibrators shall be selected from Table 5.2.1 below:

<table>
<thead>
<tr>
<th>Size of Pour (m³/h)</th>
<th>Poker Diameter (mm)</th>
<th>Speed (Vibrations/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 - 4</td>
<td>20 - 45</td>
<td>9000</td>
</tr>
<tr>
<td>5 - 10</td>
<td>50 - 65</td>
<td>9000</td>
</tr>
<tr>
<td>10 - 20</td>
<td>60 - 75</td>
<td>7000</td>
</tr>
<tr>
<td>20 - 30</td>
<td>80 - 115</td>
<td>7000</td>
</tr>
<tr>
<td>30 - 40</td>
<td>140 - 170</td>
<td>6000</td>
</tr>
</tbody>
</table>

B.2 Poker vibrators shall be inserted into the concrete vertically at regular intervals which shall be no greater than 0.5m. They shall be inserted quickly and withdrawn slowly. The withdrawal rate shall be not more than 75mm/sec. the cycle of insertion and withdrawal shall be between 10 and 30 seconds.

B.3 Poker vibrators shall be kept clear of formwork and concrete previously cast.

B.4 Vibrators shall be manipulated to work the concrete thoroughly around the reinforcement and embedded fixtures and into the corners and angles of forms. Vibrators shall not be used to make concrete flow or run into position in lieu of placing.
B.5 Compaction shall be sufficient to achieve the maximum density without segregation in the fresh concrete.

B.6 Standby pokers of the same type shall be provided at all times. The number of spares shall be not less than half the number of pokers used for compaction of the pour.

B.7 Vibration shall only be carried out by operatives having previous experience in this type of work.

C. Other Vibrators

C.1 Form vibrators, vibrating tables and surface vibrators where required shall first be approved by the Engineer and shall conform to the requirements of ACI-309.

C.2 Where form vibrators are used, the form shall be adequately designed so that the vibration does not cause joints to leak or dimensions and geometry to alter.

C.3 Unless otherwise permitted by the Engineer, the use of form vibrators shall be limited to members whose thickness does not exceed 150 mm.

5.02.5 CURING

A. Materials

A.1 Hessian or Burlap shall be clean and free from harmful materials. The unit weight of either hessian or burlap shall be not less than 230g/ m².

A.2 Impermeable membranes: The following impermeable membranes may, with the Engineer's approval, be used.
- Clear polyethylene film with no holes, tears, scratches or contamination of any type.
- Hessian coated with white polyethylene of density not less than 300g/sq.m. The coating may be on one side only but shall be not less than 0.1mm thick and shall not peel during and after use.

A.3 Curing Compounds shall conform to AASHTO M148 (ASTM-C309).

A.4 Sand shall be natural sand, free of silt, clay and other contaminants harmful to the concrete.

A.5 Water shall satisfy the requirements of Section 5.01 of the Specification.
B. Method of Curing

B.1 General: The method of curing shall be approved by the Engineer. It shall not cause any undesirable blemishes such as surface discoloration and surface roughness. Curing compounds shall not be used on construction joints and surfaces that are to receive waterproofing, paint or membranes.

B.2 Ponding: Curing by ponding may be used for horizontal surfaces such as bases, pile caps and slabs. Large horizontal surface areas shall be separated into ponds not exceeding 5 m². The ponds shall first be filled between 12 to 24 hours after the pour, unless otherwise authorised by the Engineer, and shall be replenished from time to time so as to maintain the ponding for the specified curing period. The temperature of the curing water shall be not greater than 10°C.

B.3 Sprinkling: Unless otherwise approved by Engineer, curing by spraying shall commence between 12 and 24 hours after the concrete pour. The concrete shall be maintained in a damp condition at all times during the curing period by periodic light spraying.

B.4 Wet Hessian/Burlap: Members to be cured by wet hessian or wet burlap shall be completely wrapped with the material which shall be kept moist at all times by regular spraying during the curing period. Unless otherwise approved by the Engineer, the overlap under normal conditions shall be not less than one-quarter the width of the hessian or burlap and not less than one-half the width in windy and/or rainy conditions. Before members are wrapped for curing, they shall first be evenly moistened. Unless approved by the Engineer, burlap shall be supplied only in rolls; burlap bags shall not be used. Second-hand hessian and burlap, if approved for use, shall be clean without holes and contamination of any kind.

B.5 Waterproof Sheets: Waterproof sheets used for curing shall, unless directed by the Engineer, be spread immediately after the pour. The sheet shall be clear of the concrete surface but be arranged to prevent air movement over the concrete surface. Waterproof sheets shall not be used when the air temperature is 25°C or higher.

B.6 Curing Compounds: Curing compounds shall be applied in two applications at a rate of not less than 1 litre/ 7.5 m² per application or as recommended by the manufacturer.

- The first coat shall be applied immediately after the removal of the forms and acceptance of the concrete finish and after the disappearance of free water on unformed surfaces. If the concrete is dry or becomes dry, it shall be thoroughly wet with water and curing compound applied just as the surface film of water disappears. The second application shall be applied after the first application has set. During curing operations, any unsprayed surfaces shall be kept wet with water. The curing membrane shall not be allowed on areas against which further concrete is to be placed.
- Hand operated spray equipment shall be capable of supplying a constant and uniform pressure to provide a uniform and adequate distribution of the curing membrane at the rates required. The curing compound shall be thoroughly mixed at all times during usage.

- The curing membrane shall be protected against damage for the entire specified curing period. Any coating that has been damaged or otherwise disturbed shall be given an additional coating. Should the curing membrane be continuously subjected to damage, the Engineer shall instruct wet burlap, polyethylene sheeting or other material to be applied at once.

- No traffic of any kind shall be permitted on the curing membrane until the curing period is completed, unless agreed to by the Engineer. Areas damaged by traffic shall be immediately repaired as directed by the Engineer.

B.7 Steam Curing

Low pressure steam curing shall be carried out in accordance with ACI 517 recommendations and high pressure steam curing in accordance with ACI 516.

C. Curing Time

C.1 The minimum curing time shall be the number of days given in Table 5.2.2 below. If the surface temperature of the concrete falls below 10°C the curing time shall be calculated from the equivalent maturity criteria.

**TABLE 5.2.2: NORMAL CURING PERIODS**

<table>
<thead>
<tr>
<th>Ambient Weather Conditions</th>
<th>Minimum Number of Days of Curing Protection where the Surface Temperature of the Concrete Exceeds 10°C for the Whole Curing Period</th>
<th>Equivalent Maturity in Degree Celsius Hours – (The required number of hours of curing of the Concrete multiplied by the Number of °C by which the initial surface temperature of the Concrete exceeds minus 10°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OPC or RHPC</td>
<td>SRPC</td>
</tr>
<tr>
<td>Hot Weather* or Drying Winds</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Other Conditions</td>
<td>3</td>
<td>2</td>
</tr>
</tbody>
</table>

**KEY.**

OPC = Ordinary Portland cement.
RHPC = Rapid-hardening Portland cement.
SRPC = Sulphate resisting Portland cement.
* See Clause 5.02.6A

C.2 The minimum curing time given in Table 5.2.2 above shall be compared with the time required for cylinders (or cubes), cured under identical conditions to those which the concrete is subjected, to attain 70% of the characteristic strength. The greater shall be taken as the minimum curing time.
5.02.6 HOT WEATHER CONCRETING

A. Definitions

For the purpose of this sub-section of this Specification, Hot Weather is as defined in ACI 305R-77 (Revised 1982) Chapter 1.

B. General

B.1 The production, delivery, placing, curing, testing and inspection of concrete shall be in accordance with these Specifications and the recommendations of ACI 305R-77 (Revised 1982).

B.2 No concreting shall commence when the air temperature is 32°C and rising. The Contractor shall schedule his operations to place and finish concreting during the hours that the air temperature will be below 32°C. This should preferably be in the latter part of the day after the maximum temperature has been reached.

C. Control of Temperature

C.1 Aggregate stockpile shall be protected from direct sunlight by suitable covering and periodically sprayed with clean water.

C.2 Water shall be stored in tanks away from sunlight and insulated by suitable means to protect against high air temperatures. Water tanks liable to be exposed to sunlight shall be covered with suitable reflective paint such as white gloss.

C.3 Sufficient ice shall be added to the mix water to ensure that the temperature of the fresh concrete shall not exceed 32°C.

C.4 The temperature of the concrete at the time of placing shall not be permitted to exceed 33 °C. Concrete materials shall be stored in a cool shaded position away from the direct rays of the sun. Prior to mixing, aggregates shall be cooled and water shall be cooled by means of a proprietary water chilling plant as necessary. The prices in the Bill of Quantities shall be deemed to cover all such special work.

C.5 Additives as recommended in ACI 305R-77 shall be used to improve workability and/or delay initial setting.

C.6 Retarding admixtures to facilitate placing and finishing of the concrete shall conform to AASHTO M194, Type D and only be used if approved by the Engineer.
D. Mixing and Placing

D.1 The Contractor shall take appropriate precautionary measures when handling and placing of concrete during periods of high temperatures. Concrete shall be covered with damp hessian during transportation. No additional water shall be added at the time of mixing without the approval of the Engineer, to minimise the risk of additional shrinkage of the concrete. Water shall not be added during transportation or placing of the concrete.

D.2 Aggregates and cement shall be thoroughly pre-mixed before adding water.

D.3 Transit mixers, if used, shall be coated with a reflective paint and shall be kept out of direct sunlight while waiting to be discharged.

E. Concrete Protection

E.1 Before the concrete shutters are struck, the formwork and shuttering shall be cooled with a water spray.

E.2 The concrete and the falsework shall be protected against sunlight.

E.3 Hessian, if used for curing, shall be coated with a white polyethylene backing.

E.4 Concrete exposed to strong winds shall be protected with windbreaks. The windbreaks shall be kept moist by regular spraying.

5.02.7 COLD WEATHER CONCRETING

A. Definitions

For the purpose of this sub-section of this Specification, Cold Weather is as defined in ACI 306.1-87, Section 1, Part 1.2.

B. General


B.2 The production and delivery of concrete, the placing and curing and the protection requirement shall be in accordance with the recommendations of ACI 306R-88 "Cold Weather Concreting".

B.3 No concreting shall commence when the air temperature is 6°C and falling, unless authorised by the Engineer.
C. Mixing and Placing

C.1 Aggregates, water, forms, reinforcement etc. shall be free of snow, frost or ice.

C.2 If aggregates and water are pre-heated, they shall be mixed together prior to introducing cement. The aggregates shall not be pre-heated to a temperature in excess of 100°C, the water shall not be in excess of 60°C and the temperature of the water and aggregate mix, before the introduction of cement, shall not exceed 38°C.

C.3 If heated water is added to unheated aggregates, the temperature of the water and aggregate mix, before the introduction of cement, shall not exceed 38°C.

C.4 The temperature of concrete at the time of discharge shall be between 10°C and 27°C and for three days after the pour not less than 5°C.

D. Protection

D.1 Concrete shall be protected against cold winds by suitable windbreaks.

D.2 Adequate insulation using boards, planks, sheets etc. shall be provided to maintain the required minimum concrete temperature during the curing period.

D.3 Protection measures shall be maintained until the concrete attains a strength of at least 65% of the characteristic strength.

5.02.8 NIGHT CONCRETING

A. Night concreting shall not be carried without prior approval from the Engineer.

B. Details of the lighting system shall be submitted in advance of the proposed concreting for the Engineer's approval. At least one stand-by generator shall be provided at all times during concreting operation.

5.02.9 MEASUREMENT

The provisions of this section of the Specification are not measured directly for payment but shall be considered subsidiary to the different classes of concrete described and measured for payment under the provisions of Specification Section 5.01: Concrete Mixes and Testing.
SECTION 5.03: STEEL REINFORCEMENT

5.03.1 SCOPE

The work covered in this Section consists of the supply and fixing of the unstressed steel bars, wires, mesh and mats for the reinforcement of concrete in accordance with the Drawings and Specification.

5.03.2 MATERIALS

A. Reinforcing Bars

A.1 High tensile steel reinforcement bars shall conform to AASHTO M31 (ASTM A615) Grade 60 (with carbon content not exceeding 0.3%) or to BS 4449:2005.

A.2 Mild steel reinforcing bars shall conform to AASHTO M31 (ASTM A615) Grade 40 or BS 4449:2005.

A.3 High tensile, low-alloy steel deformed bar shall conform to ASTM A706.

B. Welded Fabric Reinforcement

B.1 Welded steel wire fabric shall conform to AASHTO M55 (ASTM A185) or BS 4482:2005.

B.2 Cold drawn steel wire shall conform to the requirements of AASHTO M32 or in the case of hard drawn steel wire to BS 4482:2005.

C. Fabricated Mat Reinforcement

Fabricated mat reinforcement shall conform to AASHTO M54 (ASTM A184).

D. Certification and Identification

D.1 Three copies of a Mill Test Report shall be supplied to the Engineer for each lot of billet steel reinforcement supplied for use on the Contract. The Mill Test Report shall give the following information:

- The processes used in the manufacture of the steel from which the bars were rolled.
- Identification of the furnaces and/or each lot of steel from which the bars were rolled.

D.2 The bars in each lot shall be legibly tagged by the manufacturer and/or fabricator. The tag shall show the manufacturer's test and lot number or other designation that will identify the material with the certificate issued for the lot of steel.
D.3 The fabricator shall furnish 3 copies of a certificate which shows the heat number or numbers from which each size of bar in the shipment was fabricated.

E. Inspection and Sampling

The sampling and testing of reinforcement bars shall be made at the source of supply when the quantity to be shipped or other conditions warrant such procedure. Bars not inspected and sampled before shipment shall be inspected and sampled after arrival at the site.

5.03.3 CONSTRUCTION

A. General

A.1 Reinforcing steel shall be protected at all times from damage. All reinforcement shall be free from dirt, mill scale, scaly rust, paint, grease, oil or other foreign substances. There shall be no evidence of pitting or visual flaws in the test specimens or on the sheared ends of the bars.

A.2 Rust shall be removed by wire brushing or by sand blasting. Light rust without visible sign of peeling need not be removed.

B. Storage

B.1 Reinforcement shall be stored clear of the ground on platforms, skids or other supports and be protected against contamination by dirt, grease, oil etc. If directed by the Engineer, the Contractor shall provide cover to the reinforcement.

B.2 Reinforcement of different grades and different diameters shall be stored separately and appropriately marked to facilitate inspection and checking.

C. Cutting and Bending

C.1 Cutting and bending of reinforcement shall be based on bar bending schedules detailed on the Drawings and/or approved by the Engineer.

C.2 Reinforcement shall be cut using specialist cutting machines or cold cut by hand only. Cutting with oxyacetylene torches is not permitted.

C.3 Bars shall be bent to the following bend diameters:

<table>
<thead>
<tr>
<th>Bar Diameter (d)</th>
<th>Mild Steel</th>
<th>High Yield Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 16 mm</td>
<td>4d</td>
<td>4d</td>
</tr>
<tr>
<td>16 to 25 mm</td>
<td>4d</td>
<td>6d</td>
</tr>
<tr>
<td>25 to 35 mm</td>
<td>6d</td>
<td>8d</td>
</tr>
<tr>
<td>35 to 60 mm</td>
<td>10d</td>
<td>10d</td>
</tr>
</tbody>
</table>
C.4 All reinforcement shall be bent within the temperature range of 5°C and 100°C. Bending by heating shall not impair the physical and mechanical characteristics of the bar.

C.5 The straight bar length for a hook of 180° shall be not less than 4 times the bar diameter or 60mm whichever is the larger.

C.6 The straight bar length of a hook of 90° shall be not less than 12 times the bar diameter.

C.7 The straight bar length after a hook in stirrups shall be 6 times the bar diameter or 60mm whichever is the larger.

C.8 Cold worked bars and hot rolled high yield bars shall not be re-bent or straightened once having been bent, unless otherwise shown on the Drawings. Where it is necessary to bend mild steel bars projecting from the concrete, the bend diameter shall comply with the requirements of item C.3 above.

C.9 If bending of a bar causes the bar to crack, the bar shall be rejected, irrespective of any prior approval that may have been given, and removed from the Site.

C.10 Bars shall be cut and bent to the following tolerances:

<table>
<thead>
<tr>
<th>Bar Length (mm)</th>
<th>Tolerance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 1000</td>
<td>5</td>
</tr>
<tr>
<td>1000 - 2000</td>
<td>+5, -10</td>
</tr>
<tr>
<td>Above 2000</td>
<td>+5, -25</td>
</tr>
</tbody>
</table>

C.11 No adjustment to bar length after bending shall be permitted.

D. Fixing

D.1 Reinforcement shall be placed and maintained in the position shown on the Drawings. Unless agreed otherwise by the Engineer, all bar intersections shall be securely tied together with the ends of the wire turned into the main body of the concrete. 1.2 mm diameter stainless steel wire shall be used for in-situ members having exposed soffits; 1.6 mm diameter soft annealed iron wire shall be used elsewhere.

D.2 The correct cover to reinforcement on all exposed faces of concrete shall be maintained by using proprietary spacers. Where instructed by the Engineer the adequacy of such spacers shall be demonstrated by site trials.

D.3 Concrete cover blocks shall be of suitable dimensions and designed so that they shall not overturn when the concrete is placed. They shall be made with 10 mm maximum size aggregate and the mix proportion shall be such as to produce at least the same strength as the adjacent concrete. Tying wire shall be cast in the blocks for subsequent attachment to the reinforcement.
D.4 Wherever it is necessary for the Contractor to splice reinforcement at positions other than those shown on the Drawings, the approval of the Engineer shall be obtained. Splices shall be staggered where possible and shall be designed to develop the strength of the bar without exceeding the allowable unit bond stress.

D.5 Proprietary mechanical splicing devices shall be used only with the prior approval of the Engineer. They shall be able to withstand without slippage a force of not less than 1.25 times the characteristic yield stress of the smaller spliced bar multiplied by the cross-sectional area of the smaller bar.

D.6 Mesh reinforcement shall comply with the sizes of sheets and diameter and spacing of bars as shown on the Drawings. The sheets of mesh shall be lapped as shown on the Drawings. The method of placing and securing the mesh in position shall be approved by the Engineer.

D.7 Welding of reinforcement bars, if permitted, shall be carried out in accordance with the latest publications of the American Welding Society publication "Structural Welding Code for Reinforcing Steel", and shall be able to withstand a force of not less than 1.25 times the characteristic yield stress of the smaller of the welded bars multiplied by the cross-sectional area of the smaller bar.

D.8 Cold worked steel bars shall not be welded.

D.9 Galvanizing or epoxy coating shall be applied to the reinforcement in accordance with the Drawings or where otherwise required with the approval of the Engineer.

D.10 Dowel bars shall be coated over half of each bar with a proprietary debonding compound or fitted with plastic sleeving to the approval of the Engineer. Bars shall be fixed securely at the required level at right angles to and centred on the joint. Compressible caps shall be fitted to debonded ends of bars where necessary in the opinion of the Engineer.

5.03.4 MEASUREMENT

A. Measurement of different grades of steel reinforcement shall be based on the theoretical quantity of metric tonnes complete in place as shown on the Drawings or placed as ordered by the Engineer. No allowance will be made for clips, wire or other fastening devices for holding the reinforcement in place. Measurement shall not be made of reinforcement chairs to separate slab steel or similar reinforcement to retain wall steel or similar usage elsewhere. Measurement of splices in reinforcement not shown on the Drawings will not be made, unless such splices were agreed or authorised by the Engineer.
B. Calculated weights for high tensile and mild steel shall be based upon Table 5.3.1.

**TABLE 5.3.1: WEIGHTS OF REINFORCING BARS**

<table>
<thead>
<tr>
<th>Diameter (mm)</th>
<th>Weight (kg/m)</th>
<th>Diameter (mm)</th>
<th>Weight (kg/m)</th>
<th>Diameter (mm)</th>
<th>Weight (kg/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.154</td>
<td>18</td>
<td>2.000</td>
<td>32</td>
<td>6.310</td>
</tr>
<tr>
<td>6</td>
<td>0.222</td>
<td>20</td>
<td>2.470</td>
<td>34</td>
<td>7.130</td>
</tr>
<tr>
<td>7</td>
<td>0.302</td>
<td>22</td>
<td>2.980</td>
<td>36</td>
<td>7.990</td>
</tr>
<tr>
<td>8</td>
<td>0.395</td>
<td>24</td>
<td>3.550</td>
<td>38</td>
<td>8.900</td>
</tr>
<tr>
<td>10</td>
<td>0.617</td>
<td>25</td>
<td>3.850</td>
<td>40</td>
<td>9.870</td>
</tr>
<tr>
<td>12</td>
<td>0.888</td>
<td>26</td>
<td>4.170</td>
<td>45</td>
<td>12.500</td>
</tr>
<tr>
<td>14</td>
<td>1.210</td>
<td>28</td>
<td>4.830</td>
<td>50</td>
<td>15.400</td>
</tr>
<tr>
<td>16</td>
<td>1.580</td>
<td>30</td>
<td>5.550</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

C. Separate measurement shall not be made for bars of different diameters but of the same grade.

D. Fabric mesh reinforcement shall be measured separately and based on the theoretical quantity of metric tonnes complete in place as shown on the Drawings or placed as ordered by the Engineer. No separate measurement shall be made for different mesh sizes or different wire diameters.

**PAY ITEMS**

<table>
<thead>
<tr>
<th>PAY ITEMS</th>
<th>UNIT OF MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5.3.1) Mild steel bar reinforcement</td>
<td>Tonne (T)</td>
</tr>
<tr>
<td>(5.3.2) High tensile steel bar reinforcement</td>
<td>Tonne (T)</td>
</tr>
<tr>
<td>(5.3.3) Fabric wire mesh reinforcement</td>
<td>Tonne (T)</td>
</tr>
<tr>
<td>(5.3.4) Fabric bar mesh reinforcement</td>
<td>Tonne (T)</td>
</tr>
</tbody>
</table>
SECTION 5.04: FORMWORK AND FALSEWORK

5.04.1 SCOPE

The work covered in this section consists of the design, supply and use of formwork and falsework for the construction of concrete highway structures.

5.04.2 DEFINITIONS

A. Formwork

The section of the temporary works used to give the required shape and support to poured concrete. It consists primarily of sheeting material, such as wood, plywood, metal or plastic sheet in direct contact with the concrete; and joists or stringers directly supporting the sheeting.

B. Falsework

Any temporary structure used to support a permanent structure while it is not self-supporting.

C. Scaffold

A temporary structure that provides access to and/or a working platform for labour, materials, plant and/or equipment.

D. Tower

A composite structure, usually tall, used principally to carry vertical loading.

E. Camber

The intentional curvature of the formwork, formed initially to compensate for subsequent deflection under load.

5.04.3 MATERIALS

A. Wood

A.1 Soft wood shall be free of faults such as splitting, warping, bending, knots etc.

A.2 The minimum grade of softwood used for falsework shall be SC3, determined in accordance with B.S 4978:1996.
A.3 Hardwood used as load-bearing wedges and packing shall be limited to those listed in Table 5.4.1.

**TABLE 5.4.1: PERMITTED HARDWOODS FOR LOAD-BEARING WEDGES AND PACKING**

<table>
<thead>
<tr>
<th>Standard Name</th>
<th>Botanical Species</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ash</td>
<td>Fraxinus excelsior</td>
</tr>
<tr>
<td>Beech</td>
<td>Fagus sylvatica</td>
</tr>
<tr>
<td>Greenheart</td>
<td>Ocotea rodiaei</td>
</tr>
<tr>
<td>Jarrah</td>
<td>Eucalyptus marginata</td>
</tr>
<tr>
<td>Karri</td>
<td>Eucalyptus diversicolor</td>
</tr>
<tr>
<td>Keruing</td>
<td>Dipterocarpus spp</td>
</tr>
<tr>
<td>Oak</td>
<td>Quercus spp</td>
</tr>
</tbody>
</table>

B. Plywood

When plastic coated plywood is used, the phenol resin on melamine shall be not less than 20% of the total coating weight.

C. Steel

Steel forms shall conform to the requirements of Section 5.16 Structural Steelwork and Metal Components.

D. Aluminium

Aluminium forms shall conform to the requirements of ASTM B221.

E. Other Materials

Other material such as fibre-glass reinforced plastic, polystyrene, polyethylene, PVC, rubber, concrete, and brick shall be permitted for use in formwork if indicated on the Drawings or approved by the Engineer.

5.04.4 DESIGN

A. General

A.1 Formwork and falsework shall be designed by the Contractor and submitted to the Engineer with full design calculations, detailed drawings, material specifications and test certificates for approval. Falsework shall be capable of temperature changes without causing damage to the concrete.
A.2 Falsework design shall be in accordance with B.S 5972 "Code of Practice for Falsework".

A.3 If the Contractor intends to use ready made proprietary type of falsework, he shall submit all relevant data, including independent test certificates, which will enable the Engineer to determine whether or not the Contractor's proposed falsework is acceptable.

A.4 Notwithstanding any approval of falsework design by the Engineer, the Contractor shall not be relieved of his responsibility for the adequacy and correctness of the design, manufacture and assembly of the falsework.

B. Forms and Formwork

B.1 Formwork shall be sufficiently rigid so as to prevent any grout loss during concreting and shall not distort due to environmental effects and concreting operations in order that member dimensions, shape, required finish and texture are within the tolerances specified.

B.2 Forms and formwork shall be designed to be readily assembled, stripped and transported without distortion to panels and members of the formwork.

B.3 The method of stripping forms without damaging the concrete or textured surface finish shall be fully considered in the design.

B.4 If form liners are to be used to achieve the specified surface finish, samples of a size as directed by the Engineer shall be submitted for approval.

B.5 Form lining shall not bulge, warp or blister, nor shall it stain the concrete. Form lining shall be used in the largest practicable panels to minimize joints. Small panels of the lining material shall not be permitted. The joints in the lining shall be tight and smoothly cut. Adjacent panels of form lining shall be so placed that the grain of the wood will be in the same direction (all horizontal or all vertical). Thin metal form lining is not permitted. Undressed lumber of uniform thickness may be used as backing for form lining. Wooden ply form, of adequate thickness which is properly supported to meet the above requirements, may be used in lieu of the lined forms specified herein.

B.6 Metal forms, if used, shall be of such thickness that the forms will remain true to shape. All bolt and rivet heads shall be countersunk. Clamps, pins or other connecting devices shall be designed to hold the forms rigidly together and to allow removal without injury to the concrete. Metal forms which do not present a smooth surface or do not line up properly shall not be used. Care shall be exercised to keep metal forms free from rust, grease or other foreign matter. Under such circumstances the continued use of the metal forms will depend upon satisfactory performance and their discontinuance may be required at any time by the Engineer. Steel panels or panels with metal frames and wood or combination shall be designed to leave no lipping or ridges in the finished concrete.
B.7 The width and thickness of the lumber, the size and spacing of studs and wales shall be determined with due regard to the nature of the Work and shall be sufficient to ensure rigidity of the forms and to prevent distortion due to the pressure of the concrete.

B.8 Form bolts, rods or ties and removable ties through plastic (PVC) pipes shall be made of steel. They shall be the type which permit the major part of the tie to remain permanently in the structure or removed entirely. They shall be held in place by devices attached to the wales capable of developing the strength of the ties. The Engineer may permit the use of wire ties on irregular sections and incidental construction if the concrete pressures are nominal and the form alignment is maintained by other means. Form ties shall not be permitted through forms for handrails. Pipe spreaders shall not be used unless they can be removed as the concrete is placed. Wood or metal spreaders shall be removed as the concrete is placed. The use of cofferdam braces or struts shall not be permitted except in unusual situations and with the approval of the Engineer.

B.9 Where the bottom of the forms is inaccessible, the lower form boards shall be left loose or other provisions made so that extraneous material may be removed from the forms immediately before placing the concrete.

B.10 Unless otherwise directed by the Engineer, the exterior side of forms shall be painted with an approved, good quality high gloss white oil base enamel paint prior to placing concrete. Paint shall be applied to metal forms only. When complete coverage is not obtained with one coat, the Engineer shall order additional coats as he deems necessary to obtain complete coverage. Forms shall be repainted when ordered by the Engineer.

B.11 Unless provided otherwise on the Drawings or directed by the Engineer, all exposed edges shall be bevelled by using dressed, mill cut, triangular moulding, having 20 millimetre sides.

B.12 Forms shall be maintained after erection to eliminate warping and shrinkage.

C. Falsework

C.1 Falsework and centring shall be designed to provide the necessary rigidity to support all loads placed upon it without settlement or deformation in excess of the permissible tolerance for the structure given in the Specifications. Falsework columns shall be supported on hardwood, concrete pads or metal bases to support all falsework that cannot be founded on rock, shale or thick deposits of other compact material in their natural beds. Falsework shall not be supported on any part of the structure, except the footings, without the written permission of the Engineer. The number and spacing of falsework columns, the adequacy of sills, caps and stringers and the amount of bracing in the falsework framing shall be subject to the approval of the Engineer.
C.2 All timber shall be of sound wood, in good condition and free from defects that might impair its strength. If the vertical members are of insufficient length to cap at the desired elevation for the horizontal members, they shall preferably be capped and frames constructed to the proper elevation. Ends of the vertical members shall be cut square for full bearing to preclude the use of wedges. If vertical splices are necessary, the abutting members shall be of the same approximate size, the ends shall be cut square for full bearing, and the splices shall be scabbed using a method approved by the Engineer.

C.3 The Contractor shall compute falsework settlement and deflection for bridges so that when the final settlement is complete, the structure will conform to the required camber, section and grade as shown on the Drawings.

C.4 The Contractor shall provide means for accurately measuring settlement in falsework during placement of concrete and shall provide a competent observer to observe and correct the settlement.

C.5 Screw jacks, if used, shall be designed for use with a slenderness ratio not exceeding 60. The slenderness ratio shall be taken as the ratio of the clear distance between effective bracing in both horizontal directions to the diameter of the screw jack measured at the root of the thread. The manufacturers' certificate showing the ultimate load capacity of the screw jack shall be submitted with the design calculations for the falsework. If directed by the Engineer, the Contractor shall furnish a test certificate carried out at an approved independent laboratory.

C.6 Props and towers supporting forms or partially completed structures shall be interconnected in plan orthogonally at levels to be determined in the design. They shall also be interconnected by diagonal bracings in orthogonal vertical planes.

5.04.5 FINISHES

A. Formed Finishes

A.1 Class F1. This class of surface finish denotes a special finish required from aesthetic considerations as shown on the Drawings. In addition to the requirements of Class F2 finish, the following additional requirements shall apply.

A.1.1 Finishes required on F1 surfaces shall be uniformly and consistently maintained with no variation in the colour or consistency of the concrete within the same structure. In order to achieve this, the Contractor shall make trial panels of the formed finishes specified. Panels shall be not less than 1.5 m high and 1 m wide and 250 mm thick and shall be cast in accordance with the method and materials as proposed for the actual Work.
A.1.2 The Contractor shall provide at his own expense as many panels as required by the Engineer until a satisfactory trial panel has been accepted by the Engineer. These shall include samples of piers, deck sections, retaining wall sections and/or underpass wall sections and typical precast edge unit to be cast on site using the same method as proposed for the prototypes. The Contractor shall submit to the Engineer and obtain his approval all details before commencement of trials. These samples, when approved, shall form the standard against which the corresponding finishes on the actual work will be judged. In all cases of approvals, the decision of the Engineer shall be final.

A.1.3 Samples and trial panels carried out at the place of manufacture to demonstrate to the Engineer that the forms and formliners and the methods of assembling and de-shuttering them are acceptable shall not be paid for and will not relieve the Contractor of the requirement for carrying out trial panels on site as described above.

A.1.4 If the required finish in the opinion of the Engineer, has not been obtained in the Works, the Contractor shall promptly carry out at his own expense all measures required by the Engineer to obtain the specified finish. These may include grit blasting followed by the application of polyester or epoxy paint. Where such remedial action is ordered by the Engineer, the entire exposed surface shall be so treated irrespective of whether or not the defective areas are localised or extensive.

A.2 Class F2. Formwork shall be lined with a material approved by the Engineer to provide a smooth finish of uniform appearance. This material shall leave no stain on the concrete and shall be so joined and fixed to its backing so that it imparts no blemishes. It shall be of the same type and obtained from only one source for any one structure. The Contractor shall make good any imperfections in the finish as directed by the Engineer. Internal ties and embedded metal parts shall not be permitted unless otherwise approved by the Engineer.

A.3 Class F3. Irregularities in the finish shall be no greater than those resulting from the use of wrought thick square edged boards arranged in a uniform pattern. The finish is intended to be left as struck. Imperfections such as fins and surface discoloration shall be made good as and when required by the Engineer.

A.4 Class F4. No special requirements.

A.5 Permanently exposed concrete surfaces to classes F1, F2 and F3 finish shall be protected from rust marks and stains of all kinds. Internal ties and embedded metal parts are not permitted.

A.6 The Contractor shall submit to the Engineer all details of formwork, liners, joints, and materials including fabrication drawings and stating procedures involved in the use of formwork for approval before commencement of any work on fabrication. No formwork shall be brought to site without the prior approval of the Engineer. Adequate time shall be allowed by the Contractor in his programme for these approvals after consultation with the Engineer.

B. Unformed Finishes
B.1 **Class U1.** The concrete shall be uniformly levelled and screeded to produce a plain or ridged surface as described in the Contract. No further work shall be applied to the surface unless it is used as the first stage for Class U2 or Class U3 finish.

B.2 **Class U2.** After the concrete has hardened sufficiently, the concrete Class U1 surface shall be floated by hand or machine sufficiently to produce a uniform surface free from screed marks.

B.3 **Class U3.** When the moisture film has disappeared and the concrete has hardened sufficiently to prevent laitance from being worked to the surface, a Class U1 surface shall be steel-trowelled under firm pressure to produce a dense, smooth uniform surface free from trowel marks.

### 5.04.6 TOLERANCES

A. The tolerances in the forms and formwork shall be such that members formed shall be within the tolerances for the size and type of the member specified elsewhere in the Specification.

B. Falsework shall be fixed such that the completed structure shall be within the required tolerances in plan, elevation and slope for the size and type of structure specified elsewhere in the Specification.

C. Surfaces which are to receive deck waterproofing shall be finished to an accuracy such that when tested with a three meter long straight edge, the maximum depression shall not exceed five mm.

### 5.04.7 CONSTRUCTION REQUIREMENTS

A. The forms and falsework shall be inspected by the Engineer after assembly on the work area and immediately before concreting. No pour shall commence until the forms and falsework have been approved by the Engineer.

B. The inside surfaces of all forms shall, except for pavement formwork, or unless otherwise agreed by the Engineer, be coated with a release agent approved by the Engineer. Release agents shall be applied strictly in accordance with the manufacturer's instructions and shall not come into contact with the reinforcement or prestressing tendons and anchorages. Only one type of release agent shall be used in formwork which will be visible in the finished work.

C. Immediately before concrete is placed, all forms shall be thoroughly cleaned.

D. Forms that are to be re-used shall be thoroughly cleaned and re-oiled and, if necessary, shall be reconditioned by revision or reconstruction. Unsatisfactory lumber shall be condemned by the Engineer and shall be removed from the Site.
E. Formwork shall be constructed so that the side forms of members can be removed without disturbing the soffit forms. If props are to be left in place when the soffit forms are removed, these props shall not be disturbed during the striking.

F. Runways used to move plant, equipment or materials shall be clear of the reinforcement and shall be robust enough not to deflect excessively or cause movement to the forms due to dynamic effects.

G. During concreting, the forms and their supports shall be constantly monitored for signs of imminent failure. Skilled operatives shall be in constant attendance during concreting who are qualified to make immediate adjustments to the forms and falsework so that concreting can satisfactorily be completed.

H. The Engineer shall suspend concreting operations if, in his opinion, the forms and falsework are in danger of failure and that the actions taken by the Contractor is insufficient or inadequate to guarantee the safe and satisfactory completion of concreting. In such an event, the Engineer shall instruct the Contractor to remove, at his expense, the concrete already poured.

I. If at any period of work, during or after placing of concrete, the forms show signs of sagging or bulging, the Contractor, at his own expense, shall remove the concrete to the extent directed by the Engineer, bring the forms to the proper position, and place concrete.

J. Immediately after the removal of the forms, all fins caused by form joints and other projections shall be removed and all pockets cleaned and filled with a cement mortar composed of 1 part by volume of Portland cement and 2 parts sand. Sufficient white Portland cement shall be mixed with the cement in the mortar, so that when dry the colour matches the surrounding concrete. Patches shall be moistened prior to mortaring to obtain a good bond with the concrete. When directed by the Engineer, the Contractor shall at his own expense, substitute an approved epoxy grout for the Portland cement mortar or provide an epoxy bonding agent to be used in conjunction with the Portland cement mortar. If, in the judgement of the Engineer, pockets are of such extent or character as to materially affect the strength of the structure or to endanger the life of the steel reinforcement, he may declare the concrete defective and require the removal and replacement of that portion of the structure affected. The resulting surfaces shall be true and uniform. Portions of the structure which cannot be finished or properly repaired to the satisfaction of the Engineer shall be removed.
5.04.8 REMOVAL OF FORMWORK AND FALSEWORK

A. To facilitate finishing, forms on handrails, ornamental work, and other vertical surfaces that require a rubbed finish, shall be removed as soon as the concrete has hardened sufficiently that it will not be injured, as determined by the Engineer. In determining the time for the removal of forms, consideration shall be given to the location and character of the structure, weather and other conditions influencing the setting of the concrete.

B. Formwork shall be removed without causing damage to the concrete and after sufficient time to allow for adequate curing and to prevent restraint that may arise from elastic shortening, shrinkage or creep.

C. Any remedial treatment to surfaces shall be agreed with the Engineer following inspection immediately after removing the formwork and shall be carried out without delay. Any concrete surface which has been treated before being inspected by the Engineer shall be liable to rejection.

D. Where the concrete compressive strength is confirmed by tests on concrete cylinders (or cubes) stored under conditions approved by the Engineer, formwork supporting concrete in bending may be struck when the strength is 10 N/sq. mm or three times the stress to which it will be subjected, whichever is the greater.

E. For ordinary structural concrete made with ordinary Portland cement, in the absence of control cylinders (cubes) the period before striking shall be in accordance with the minimum periods given in Table 5.4.2 unless otherwise directed by the Engineer.

TABLE 5.4.2: MINIMUM PERIOD BEFORE STRIKING FOR STRUCTURAL CONCRETE MADE WITH ORDINARY PORTLAND CEMENT

<table>
<thead>
<tr>
<th>Type of Formwork</th>
<th>Minimum Period before striking at Surface Temperature of Concrete</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>16°C</td>
</tr>
<tr>
<td></td>
<td>12 hours</td>
</tr>
<tr>
<td>Vertical formwork to columns, walls and large beams</td>
<td>4 days</td>
</tr>
<tr>
<td>Soffit formwork to slabs</td>
<td>10 days</td>
</tr>
<tr>
<td>Props to slabs</td>
<td>9 days</td>
</tr>
<tr>
<td>Soffit to formwork to beams</td>
<td>14 days</td>
</tr>
<tr>
<td>Props to beams</td>
<td>10 days</td>
</tr>
</tbody>
</table>
5.04.9 MEASUREMENT

A. The provisions of this section of the Specification are not measured directly for payment but shall be considered subsidiary to the different classes of concrete described and measured for payment under the provisions of Section 5.01 "Concrete and Concrete Mixes and Testing" of the Specification.

B. Test panels carried out by the Contractor to demonstrate to the Engineer's satisfaction that the specified F1 finish can be achieved shall be measured for payment for the appropriate class of concrete measured for payment under the provisions of Section 5.01 "Concrete and Concrete Mixes and Testing" of the Specification. Test panels not accepted by the Engineer shall not be measured for payment.

C. Test samples, such as a section of retaining wall or a complete pier, carried out by the Contractor and approved by the Engineer for use as reference bench marks for the quality to be attained in the Works shall be measured for payment for the appropriate class of concrete measured for payment under the provisions of Section 5.01 "Concrete and Concrete Mixes and Testing". Test samples not accepted by the Engineer shall not be measured for payment.
SECTION 5.05: CONCRETE PAVEMENT

5.05.1 SCOPE

The work covered in this section consists of furnishing materials and constructing cement concrete pavement, with or without reinforcement, on a prepared base all as and where shown on the Drawings.

5.05.2 MATERIALS

A. The class and strength of concrete for pavement construction shall be as shown on the Drawings.

B. Concrete shall conform to the relevant requirements of Section 5.01 Concrete, Mixes and Testing.

C. Chemical admixtures shall conform to the relevant requirements of Section 5.01 Concrete, Mixes and Testing, sub-section 5.01.2.

D. Steel reinforcing bars and steel wire fabric shall conform to the relevant requirements of Section 5.03: Steel Reinforcement.

E. Dowel bars shall be plain steel bars conforming to AASHTO M 31M (ASTM A 615M) Grade 40 or 60. Sleeves for dowel bars shall be approved types. Tie bars shall be deformed steel bars of approved type and shall conform to AASHTO M 42. (ASTM A996).

F. Water for use in concrete and mortar mixes and for curing purposes shall conform to the relevant requirements of Section 5.01 Concrete, Mixes and Testing.

G. Curing membrane materials shall conform to the relevant requirements of Section 5.02 "Concrete Handling. Placing and Curing". Unless otherwise shown on the Drawings, a liquid curing compound conforming to AASHTO M 148. (ASTM C 309) shall be used.

H. Moisture barriers (for spreading on the granular base prior to placing concrete) shall be either PVC plastic film conforming to ASTM D 1593, Type II or PE plastic film conforming to ASTM D 2103, Type 2000. The film shall be 0.15 to 0.20 mm in thickness.

I. Materials for use in expansion joints, construction joints and weakened plane joints shall be approved proprietary sealants, fillers and plastic strips, as shown on the Drawings and conforming to the relevant requirements of Section 5.21: Joint Sealing and Joint Filler.

J. Poured filler shall conform to AASHTO M 173 (ASTM D 1190). Preformed fillers shall conform to AASHTO M 33, (ASTM D 994) AASHTO M 153, (ASTM D 1752) AASHTO M 213 (ASTM D 1751) or AASHTO M 220. (ASTM D 2628) as appropriate and shall be punched to admit dowels where required. Preformed filler for each joint shall be furnished in a single piece unless otherwise approved by the Engineer.
5.05.3  EQUIPMENT

A.  Plant and equipment for base course and concrete pavement construction shall conform to the requirements of Section 1.06: Contractor's Plant and Equipment and with the Contractor's approved Programme of Works.

B.  Stationary side forms or slip-form paving equipment shall be used for concrete pavement construction unless otherwise shown on the Drawings or agreed by the Engineer.

5.05.4  BASE COURSE SURFACE PREPARATION

A.  Base course provided immediately beneath the concrete pavement shall have been constructed in accordance with Section 3.03: Aggregate Base Course.

B.  Immediately prior to placing concrete, the base course surface shall be inspected and approved by the Engineer to ensure that it conforms to the compaction and level tolerances specified.

C.  Moisture barrier material shall be placed over the base course surface prior to placing concrete. All seams shall be lapped by at least 150 mm and the barrier material anchored in place using a method approved by the Engineer.

D.  Storing or stockpiling of other equipment and materials on the base course shall not be permitted.

5.05.5  PREPARATORY WORKS

A.  Before placing concrete, the Contractor shall provide a sufficient supply of water and ensure that it will remain available throughout the pavement construction period. An inadequate water supply will be considered sufficient cause for delaying or stopping mixing operations. In case of a deficiency of water, the requirements for curing concrete already placed shall take precedence.

B.  Slip-form paving and finishing machines shall be correctly adjusted and in a satisfactory working order. Prior to placing concrete, the Contractor shall demonstrate the correct adjustment of all screeds and floats on slip-form pavers using measurements from grade stakes driven to known elevations. Satisfactory operation and adjustment of all propulsion and control equipment, including pre-erected grade and alignment lines, shall be demonstrated by moving slip-form pavers and finishing machines over a 100 m length of prepared base course with all propulsion and control equipment fully operational.

C.  The Contractor shall make adequate advance arrangements for preventing delay in delivery and placing of the concrete. An interval of more than 45 minutes between placing of any 2 consecutive batches or loads shall constitute cause for stopping paving operations.
5.05.6 TRIAL LENGTH

A. General

A.1 At least one month prior to the construction of the trial length of surface slabs the Contractor shall submit for the Engineer's approval a detailed description of the proposed materials, plant, equipment and construction methods. No trials of new materials, plant, equipment or construction methods shall be permitted either during the construction of the trial length or in any subsequent paving work, unless they form part of further approved trials.

A.2 The Contractor shall demonstrate the materials, plant, equipment and methods of construction that are proposed for concrete paving the construction of a trial length of slab, at least 150 metres but not more than 300 metres long for mechanised construction and at least 30 metres long for hand guided methods.

A.3 The trial length shall be constructed in two sections over a period comprising at least part of two separate working days, with a minimum of 75 metres constructed each day when mechanised paving plant is used and a minimum of 15 metres on each day for hand guided methods. The trial length shall be constructed at a similar rate to that which is proposed for the permanent Works.

A.4 At least two transverse joints and one longitudinal joint of each type that are proposed for unreinforced concrete slabs and jointed reinforced concrete slabs in the Works shall be constructed and assessed in the trial length. If in the trial length expansion joints are not demonstrated, the first 2 expansion joints and at least the first 150 metres of longitudinal construction joint for mechanised paving, or 30 metres for hand guided method of construction laid in the permanent Works, shall be considered the trial length for these joints. One construction joint shall be demonstrated in each trial length.

B. Assessment

The trial length shall comply with the Specification in all respects.

5.05.7 CONSTRUCTION GENERAL

A. Concrete shall be handled, placed, compacted and cured in accordance with the relevant requirements of Section 5.02: Concrete Handling, Placing and Curing.

B. Steel reinforcing bars, steel wire fabric, dowel bars and tie bars shall be handled and fixed in proper positions in accordance with the relevant requirements of Section 5.03: Steel Reinforcement.

C. All concrete shall be placed while fresh. The use of water for retempering any concrete shall not be permitted. Any concrete showing improper proportions of materials, including water, shall not be used in the pavement and any such unsatisfactory concrete shall be removed and disposed of by the Contractor at his own expense.
D. Unless otherwise shown on the Drawings, concrete pavement shall be constructed in traffic lane widths separated by contact joints, or monolithically in multiples of traffic lane widths with a longitudinal weakened plane joint at each traffic lane line.

E. Concrete shall be spread, shaped and consolidated so that the completed pavement conforms to the thickness and cross sections shown on the Drawings. Sides of pavement may be constructed on a batter not exceeding 1:6 (H:V), provided the surface of the pavement is maintained at the specified width.

F. When the pavement being constructed is continuous to an existing parallel concrete pavement, the elevation of the new pavement surface shall conform as closely as possible to the elevation of the existing pavement surface and in a manner which will prevent ponding.

G. Pavement shall be constructed using paving equipment which is capable of producing a finished surface meeting straightedge tolerances. Failure of equipment in this respect shall constitute cause for suspending placement of concrete until the equipment deficiency or malfunction is corrected.

5.05.8 STATIONARY SIDE FORM CONSTRUCTION

A. Side form sections shall be straight, free from warps, bends, indentations or other defects. Defective forms shall be removed from the Works. Metal side forms shall be used except at end closures and traverse contact joints where straight forms of other suitable materials may be used.

B. Side forms shall be built up by rigidly attaching a section to either the top or bottom of forms. If the build-up is attached to the top of metal forms, it shall be made of metal.

C. Side forms shall be of sufficient rigidity, both in the form and in the interlocking connection with adjoining forms so that springing will not occur under the weight of equipment from the pressure of concrete. The Contractor shall provide sufficient forms so that there is no delay in placing concrete.

D. Before placing side forms, the base course surface shall be at the proper elevation and grade. Side forms shall have full bearing upon the base course throughout the length and width of the covered base and shall be placed to the required grade and alignment of the edge of the finished pavement. Forms shall be firmly supported during the entire operation of placing, compacting and finishing the pavement.

E. Immediately in advance of placing concrete, side forms shall be set out and maintained to the required line and grade for a sufficient distance ahead to prevent delay in placing concrete.

F. Side forms shall remain in place for 24 hours after placing the concrete, and in all cases until the edge of the pavement no longer requires the protection of the forms.
G. Side forms shall be thoroughly cleaned and oiled each time they are used and immediately before concrete is placed against them.

H. Concrete shall be spread, screeded, shaped and consolidated by one or more machines. These machines shall uniformly distribute and consolidate concrete without segregation and so that the completed pavement will conform to the required cross sections with a minimum of handwork. The number and capacity of machines furnished shall be adequate to perform the Works required at a rate equal to that of concrete delivery.

I. Concrete shall be effectively consolidated over the full paving width by means of surface vibrators, internal vibrators or by other method of consolidation that produces equivalent results without segregation.

J. When vibrators are used to consolidate concrete, the rate of vibration shall be not less than 3,500 cycles/minute for surface vibrators and not less than 5,000 cycles/minute for internal vibrators. The amplitude of vibration shall be sufficient to be perceptible on the surface of concrete up to 0.5 metres from the vibrating element. The Contractor shall furnish a tachometer or other suitable device for measuring and indicating frequency of vibration.

K. Vibrators shall not rest on new pavement or side forms. Power to vibrators shall be connected so that vibration ceases when forward or backward motion of the machine is stopped.

L. When concrete is being placed adjacent to an existing pavement, the part of the equipment supported on the existing pavement shall be fitted with protective pads on crawler tracks or rubber-tired wheels with the bearing surface offset to run a sufficient distance from the pavement edge to avoid breaking or cracking the edge.

M. Concrete placed at existing ramp termini, truck weigh stations, ramps, connectors with steep grades and high rates of superelevation, in short sections of city streets, on sharp curves, in short lengths or in widths other than multiples of traffic lanes shall be spread and shaped by suitable powered finishing machines, supplement by handwork as necessary. Consolidation of concrete so placed shall be completed using high frequency internal vibrators and within 15 minutes of placement. Vibration of concrete shall be carried out with care and the Contractor shall ensure adequate consolidation adjacent to forms and uniform consolidation across the full paving width. Use of vibrators for shifting masses or piles of concrete is not permitted. Methods of spreading, shaping and compaction that result in segregation, voids or rock pockets shall be discontinued. The Contractor shall adopt methods which will produce a dense and homogeneous pavement.

5.05.9 SLIP-FORM CONSTRUCTION

A. Slip-form pavers shall be equipped with travelling side forms of sufficient dimensions, shape and strength to support the concrete laterally for a sufficient length of time to produce a pavement of the required cross section. Slip-form paving equipment shall spread, consolidate and screed freshly placed concrete in order that a minimum of handwork shall be required to produce a dense homogeneous pavement.
B. No abrupt changes in longitudinal alignment of the pavement shall be permitted. The horizontal deviation shall not exceed 30 mm from the alignment shown on the Drawings.

C. Concrete shall be effectively compacted over the full paving width by high frequency internal vibrators. Vibrators shall be mounted with their axes parallel or normal to pavement alignment. When vibrators are mounted with their axes parallel with the pavement alignment, they shall be spaced at intervals not exceeding 750 mm measured centre to centre. When vibrators are mounted with their axes normal to pavement alignment, they shall be spaced so that lateral clearance between individual vibrating units does not exceed 150 mm.

D. The vibration rate of each vibrating unit shall be not less than 5,000 cycles/minute. The amplitude of vibration shall be sufficient to be perceptible on the surface of concrete along the entire length of vibrating units and for a distance up to 0.5 metres therefrom. The Contractor shall furnish a tachometer or other suitable device for measuring and indicating frequency of vibration.

E. When concrete is being placed adjacent to an existing pavement, the part of the equipment supported on existing pavement shall be fitted with protective pads on crawler tracks or rubber-tired wheels with the bearing surface offset to run a sufficient distance from the pavement edge to avoid breaking or cracking such edge.

5.05.10 CONSTRUCTION OF JOINTS

A. General

A.1 Joints in pavement shall be designated as longitudinal contact joints, transverse contact joints, longitudinal weakened plane joints and transverse weakened plane joints. Joints shall be constructed as and where shown on the Drawings and in accordance with the requirements in this section.

A.2 All transverse joints shall be constructed at the specified angle to the centreline of the pavement and the faces of all joints, both transverse and longitudinal, shall be normal to the face of the pavement.

A.3 Joints shall be maintained clean and free of all soil, sand, gravel, concrete, or asphalt mix and other foreign material until the joint filler material or sealant has been placed.

A.4 Tie bars in previously placed pavement for longitudinal joints shall not be straightened.

B. Contact Joints

B.1 Contact joints are those made by placing fresh concrete against hardened concrete.
B.2 Curing compound shall be applied to the face of each contact joint and allowed to dry prior to placing fresh concrete against that joint face. This provision is also applicable to existing concrete pavement not constructed as part of the Works.

C. Weakened Plane Joints

C.1 Longitudinal weakened plane joints shall be constructed along traffic lane lines in multilane monolithic concrete pavements by cutting grooves with a power driven saw.

C.2 Transverse weakened plane joints shall be spaced as shown on the Drawings. For unreinforced concrete slabs the spacing of transverse joints shall not exceed 4 metres and the length / width ratio shall be not greater than 2:1. This spacing may be increased, with the approval of the Engineer, if 20% limestone coarse aggregate is used throughout the depth of the slab. Transverse weakened plane joints shall be constructed by either cutting grooves with a power driven saw of the multiple-bladed span type or by inserting a plastic strip in the fresh concrete.

C.3 Sawn grooves shall be cut to a minimum depth of 50 mm and a maximum width of 6 mm. Every fourth transverse weakened plane joint in the initial lane of concrete and also the first joint immediately after the transverse contact joint shall be sawn within 24 hours after the concrete has been placed and every second transverse weakened plane joint shall be sawn within 48 hours after placing the concrete. Sawing should be undertaken as soon as possible after the concrete has hardened sufficiently to enable a sharp edged groove to be produced without disrupting the concrete and before random cracks develop in the slab. The minimum and maximum time will depend on site conditions. The exact times for such sawing shall be agreed with the Engineer.

C.4 Unless otherwise shown on the Drawings, the longitudinal and transverse weakened plane joints in the initial lane of concrete may be sawn after 24 hours but joints shall be completed before placing concrete in succeeding adjacent lanes and before the Contractor's vehicles or public traffic use the pavement.

C.5 In succeeding lanes of concrete pavement, the transverse joints opposite those which have opened in the initial lane shall be sawn within 24 hours after the concrete has been placed. The exact time shall be determined by the Engineer.

C.6 The remaining longitudinal and transverse weakened plane joints in succeeding lanes may be sawn at such time after 24 hours but they shall be completed before placing concrete in the succeeding adjacent lanes and before the Contractor's vehicles or public traffic use the pavement.

C.7 No sawing shall be carried out within 2 metres of a preformed transverse crack.

C.8 Unless otherwise shown on the Drawings, insert-type transverse weakened plane joints shall be formed by placing a continuous strip of plastic or other material which shall not react adversely with the chemical constituents of the concrete or bond.
with the concrete. The strip shall have a minimum thickness of 0.3 mm and a width of 50-55 mm.

C.9 After placement, the vertical axis of the insert-type strip shall be within 13.5 degrees of a plane normal to the surface of the pavement. The top of the strip shall not be above or more than 10 mm below the finished pavement surface. Final alignment of the strip shall be as shown on the Drawings and shall not vary by more than 30 mm from a 4 metre long straightedge.

C.10 Insert-type transverse strips shall be placed by means of a mechanical installation device which shall vibrate the plastic concrete sufficiently to cause an even flow of concrete about the joint material. After installation of the strip, the concrete shall be free of segregation, rock pockets or voids and the finished concrete surface on each side of the joint shall be in the same plane. Splices in the joint strip will not be permitted.

C.11 The Contractor shall maintain a standby multiple-bladed power driven span type joint saw, in proper operating condition, on site at all times while concrete paving operations are underway, regardless of the type of weakened plane joint being constructed.

C.12 Unless otherwise shown on the Drawings, insert-type longitudinal weakened plane joints at traffic lane lines in multilane monolithic concrete pavement shall be formed by placing a continuous strip of plastic or other material which shall not react adversely with the chemical constituents of the concrete. The joint insert material shall be of such width and type that when placed vertically in the concrete it will not bond with the concrete and will form an effective weakened plane joint to 50 mm below the finished surface of the concrete. The joint material shall not be deformed from a vertical position, either in the installation or in subsequent finishing operations performed on the concrete.

C.13 The alignment of the finished longitudinal joint shall be uniformly parallel with the centreline of the pavement and shall be free of any local irregularity which exceeds 12 mm measured by a 4 metre long straightedge, except for the normal curvature of the centreline. The mechanical installation devices shall vibrate the concrete during placing of the strip sufficient to cause the concrete to flow evenly about the joint material, producing homogeneous concrete free of segregation, pockets and voids.

5.05.11 CONCRETE SURFACE FINISH

A. Preliminary Finish

A.1 Prior to completion of float finishing and texturing, water shall not be applied to the pavement surface in excess of the amount lost by evaporation.

A.2 Placement of concrete shall cease in sufficient time to enable finishing operations to be completed during daylight hours, unless lighting facilities approved by
the Engineer as adequate for allowing later placement and finishing are provided by the Contractor.

A.3 Preliminary finishing procedures to be adopted shall be either side forms or slip-forms as described below:

B. Stationary Side Form Preliminary Finishing

B.1 After spreading and compacting, the concrete shall be given a preliminary finish by either machine float or hand methods. Hand methods shall only be permitted in the event of minor breakdown of the machine float or other such emergency. A standby machine float shall be made available by the Contractor if the Engineer deems such provision necessary to avoid undue delays.

B.2 In the case of the machine float method, self-propelled machine floats shall be used to finish the surface smooth and true to grade. The number and capacity of machine floats furnished shall be adequate to perform all finishing required at a rate equal to that at which concrete is delivered. Any delay exceeding 30 minutes in performing preliminary finishing shall constitute cause for stopping delivery of concrete until machines performing such work are again available to continue without delay.

B.3 Machine floats shall be capable of running either on side forms or on adjacent lanes of pavement. When machine floats run on adjacent pavement, the concrete surface shall be protected as specified under "Stationary Side Form Construction".

B.4 Floats shall be constructed of hardwood, steel or steel-shod wood and shall be equipped with devices to permit adjustment of the underside to a true flat surface.

B.5 In the case of hand methods, the surface shall be finished smooth and true to grade with suitable manually operated float or powered finishing machines. Finishing shall take place as far back from concrete spreading operations as the concrete remains workable. The number of finishing passes shall be sufficient to remove all perceptible inequalities.

C. Slip-Form Preliminary Finishing

C.1 The surface shall be given a preliminary float finish using devices incorporated in the slip-form paver. These shall be supplemented with suitable machine floats unless otherwise agreed by the Engineer.

C.2 Any edge slump of the pavement in excess of 5 mm, exclusive of edge rounding, shall be corrected before the concrete has hardened.
D. Final Finishing

D.1 After completion of preliminary finishing, the edges of the initial paving widths shall be rounded to 12 mm radius. Transverse contact joints, expansion joints and the edge of longitudinal contact joints adjacent to hardened concrete pavement shall be rounded to 6 mm radius.

D.2 In advance of curing operations, the pavement shall be given an initial and a final texturing. Initial texturing shall be performed with a burlap drag or broom device to produce striations normally parallel with the pavement centreline. Final texturing shall be performed with a spring steel tine device to produce grooves parallel with the centreline unless otherwise in the Drawings or directed by the Engineer. The steel tine shall not operate closer than 75 mm to the pavement edge.

D.3 Except when texturing areas of pavement finished using hand methods, burlap drags, brooms, and tine devices shall be installed on self-propelled equipment having external alignment control. The installation shall ensure that the area of burlap in contact with the pavement surface shall be maintained constant at all times when texturing.

D.4 Broom and tine devices shall be provided with positive elevation controls. The down pressure on pavement surface shall be maintained at all times during texturing to achieve uniform texturing without measurable variations in the pavement profile. Self-propelled texturing machines shall be operated so that the travel speed, when texturing, is constant.

D.5 Failure of equipment to conform to the above requirements will constitute a cause for stopping the placement of concrete until the equipment deficiency or malfunction is corrected.

D.6 Spring steel tines on the final texturing device shall be rectangular in cross section, 3-4 mm wide, 20 mm centre-to-centre and of sufficient length, thickness and resilience to form grooves approximately 5 mm deep in the fresh concrete surface. The final texture shall be uniform in appearance with all grooves having a depth of 2-5 mm. This texture pattern shall be adopted unless otherwise shown on the Drawings or directed by the Engineer.

D.7 The finished pavement shall be checked by the Engineer not more than 10 days following placement of the concrete in order to verify that it conforms to the correct line, grade and cross section.

D.8 When the finished surface is tested with a 4 metre long straightedge, placed parallel to, or at right angles to the centre, the maximum deviation of the surface from the testing edge between any two contact points shall not exceed 6 mm.

D.9 All high points which exceed the specified tolerances shall be corrected by grinding as directed by the Engineer.
D.10 The Contractor shall obtain drilled 100mm diameter cores from the completed pavement, at locations selected by the Engineer, to verify compliance with the thickness requirements. The Contractor shall fill all core holes with fresh concrete and finish the surface neatly to match the surrounding concrete.

5.05.12 CURING PROCEDURES

A. General

A.1 Immediately after the finishing process is complete, the entire exposed area of the pavement, including edges, shall be cured by the curing compound method unless approval is given by the Engineer for water curing.

A.2 If the side forms are removed less than 72 hours from the start of curing, the exposed pavement edges shall also be cured. If the pavement is cured using the curing compound method, the saw cut and all portions of the curing compound which have been disturbed by sawing operations shall be restored by spraying with additional curing compound.

A.3 When the ambient temperature is above 25 °C and whenever otherwise deemed necessary by the Engineer, the concrete shall be cooled with a fine spray of water immediately after the curing seal is applied until the Engineer determines that cooling is no longer required.

B. Curing Compound Method

B.1 Surfaces of the concrete which are exposed to the air shall be sprayed uniformly with an approved curing compound as specified in Section 5.02: Concrete Handling, Placing and Curing.

B.2 Unless otherwise shown on the Drawings, the application rate shall be 0.25 litres per square metre. The application rate shall always be within 20% of the specified application rate and the average application rate shall be within 10% of the specified application rate. Runs, sags, thin areas, skips or gaps in the applied curing compound shall be evidence that the application is unsatisfactory and the compound shall be reapplied.

B.3 Curing compound shall be applied using mechanical sprayers of the fully atomizing type, equipped with a tank agitator which shall provide for continual agitation of the curing compound during application. The power operated spraying equipment shall be equipped with an operational pressure gage and a means of controlling the pressure.

B.4 The spray shall be adequately protected against wind and the nozzles shall be so oriented or moved mechanically transversely as to result in not less than the minimum specified rate of coverage uniformly on all exposed faces.
B.5 Hand spraying of small and irregular areas and areas inaccessible to mechanical spraying equipment shall only be permitted with the consent of the Engineer.

B.6 The curing compound shall be applied before any drying shrinkage or craze cracking begins to appear. In the event of any drying or cracking of the surface-application of water with an atomizing nozzle shall be started immediately and shall be continued until application of the compound is resumed or started. The compound shall not, however, be applied over any resulting free standing water.

B.7 Should the film of compound be damaged from any cause before the expiration of seven days after the concrete is placed, the damaged portion shall be repaired immediately with additional compound.

C. Water Curing Method

C.1 When water curing is permitted by the Engineer, the concrete shall be kept continuously wet by the application of water for a minimum period of seven days after the concrete has been placed. Cotton mats, rugs, carpets or earth or sand blankets shall be used as a curing medium to retain the moisture during the curing period.

C.2 The entire surface of the concrete shall be kept damp by applying water with a atomising nozzle so that a mist and not a spray is formed, until the surface of the concrete is covered with the curing medium.

C.3 The moisture from the nozzle shall not be applied under pressure directly upon the concrete and shall not be allowed to accumulate on the concrete in a quantity sufficient to cause a flow or to wash the surface. At the end of the curing period, the concrete surfaces shall be entirely cleared of curing medium.

C.4 When the concrete is to be water cured without the use of a moisture retaining medium, the entire surface of the pavement shall be kept damp by the application of water with the atomizing nozzle, until the concrete has set, after which the entire surface of the concrete shall be sprinkled continuously with water for a period of not less than 7 days.

5.05.13 DETERMINATION OF CONCRETE THICKNESS

A. The thickness of the concrete pavement shall be determined by average calliper measurement of cores, rounded upwards taken to the nearest millimetre.

B. Pavement sections to be measured separately shall consist of 300 metre sections in each traffic lane. The last section in each traffic lane shall be 300 metres plus the fractional part remaining. Other areas such as intersections, entrances, crossovers or ramps shall be measured as one section each and the thickness of each shall be determined separately. Small irregular unit areas may be included as part of another section.

C. One core shall be taken from each section by the Contractor at locations approved by and in the presence of the Engineer. When the measurement of the core from any
pavement section is not deficient by more than 5 mm from the specified thickness, the core will be deemed to be of the specified thickness as shown on the Drawings.

D. When the measurement of any core a pavement section is deficient by more than 5 millimetres but not more than 20 mm, two additional cores spaced at not less than 100 mm shall be taken and used together with the first core to determine the average thickness of the section.

E. When the measurement of the core from any pavement section is less than the specified thickness by more than 20 mm, the average thickness of such section shall be determined by taking additional cores at not less than 5 metre intervals parallel to the centreline in each direction from the affected location until, in each direction, a core is taken which is not deficient by more than 20 mm. Exploratory cores for deficient thicknesses shall not be used in average thickness determinations.

F. Where the average thickness of concrete pavement is deficient by more than 5 mm but not more than 20 mm adjustments shall be made in the area measurements as shown in Table 5.5.1.
Table 5.5.1: CONCRETE THICKNESS DEFICIENCY

<table>
<thead>
<tr>
<th>Deficiency in Thickness as Determined by Cores (mm)</th>
<th>Proportion of Area Measured for Payment</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.0 to 5.0</td>
<td>100%</td>
</tr>
<tr>
<td>5.1 to 10.0</td>
<td>90%</td>
</tr>
<tr>
<td>10.1 to 15.0</td>
<td>75%</td>
</tr>
<tr>
<td>15.1 to 20.0</td>
<td>50%</td>
</tr>
</tbody>
</table>

G. Where the pavement is more than 20 mm deficient in thickness, the Contractor shall remove such deficient areas and replace them with concrete pavement of the specified quality and thickness, all at his own expense.

H. When the limits of a deficient area to be removed and replaced are within 3 metres of an expansion, contraction or construction joint, the entire concrete pavement up to the joint shall be removed and replaced at the Contractor's expense.

I. If approved by the Engineer and provided the pavement section is not deficient by more than 25 mm, the Contractor may leave the deficient concrete pavement in place, in which case no measurement for payment shall be made for the section.

5.05.14 MEASUREMENT

A. Unreinforced concrete (URC), jointed reinforced concrete (JRC) and continuously reinforced concrete (CRC) of different thickness pavements shall be measured by the square metre of concrete pavement constructed, including furnishing of all materials, placing, jointing, finishing and curing concrete, completed, and accepted. Measurements shall be of the surface area dimensions as shown on the Drawings, adjusted for the thickness deficiencies as specified.

B. Trial sections of URC. JRC or CRC pavements that demonstrate the suitability of the paving method shall be measured by the square metre and be paid for under the appropriate type of concrete pavement. Trial sections that do not conform to the Specification shall not be measured for payment.

C. Base course surface preparation, furnishing and installation of moisture barriers, excavation for thickened portions of pavement, cutting of cores from the finished pavement for testing or measurement purposes and additional thicknesses of concrete in excess of the specified thickness, shall not be measured for direct payment, but shall be considered as subsidiary works; the costs of which shall be deemed to be included in the Contract Prices for Pay Items.
<table>
<thead>
<tr>
<th>PAY ITEMS</th>
<th>UNIT OF MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5.5.1) Unreinforced Concrete Pavement (State thickness)</td>
<td>Square Metre (m²)</td>
</tr>
<tr>
<td>(5.5.2) Jointed Reinforced Concrete Pavement (JRCP) (State thickness)</td>
<td>Square Metre (m²)</td>
</tr>
<tr>
<td>(5.5.3) Continuously Reinforced Concrete Pavement (CRCP) (State thickness)</td>
<td>Square Metre (m²)</td>
</tr>
</tbody>
</table>
SECTION 5.06: PLAIN AND REINFORCED CONCRETE STRUCTURES

5.06.1 SCOPE

This Section of the Specification describes the construction of plain and reinforced concrete structures.

5.06.2 MATERIALS

A. Concrete

Concrete shall be produced and supplied in accordance with Section 5.01: Concrete Mixes and Testing.

B. Reinforcement

Reinforcement shall conform to Section 5.03: Steel Reinforcement.

C. Formwork and Falsework

Formwork and Falsework shall be designed and supplied in accordance with Section 5.04: Formwork and Falsework.

D. Plant and Equipment

Plant and Equipment shall conform with the requirements of the Specifications Part 1 Section 4-4 and shall be the type and number outlined in the Contractor's detailed Programme of Works as approved by the Engineer.

5.06.3 CONSTRUCTION

A. General

A.1 The Contractor shall notify the Engineer his intention to concrete at least 24 hours in advance.

A.2 The Engineer shall check and certify that:
- The formwork meets the Specification requirements
- The falsework and support props are in accordance with the approved Drawings.
- The reinforcement conforms to the Drawings and that the correct cover has been provided
- The forms are free of dirt and other deleterious matter.

B. Concreting
Handling, placing and curing shall be in accordance with Section 5.02: Concrete Handling, Placing and Curing.

C. Slump

Slump shall be within the limits given in Section 5.02 of the Specification except that the maximum slump of bridge deck superstructure concrete shall be 75 mm, unless otherwise agreed by the Engineer.

D. Construction and Expansion Joints

D.1 Whenever placing of concrete is delayed until after the previously placed concrete has undergone initial set, the point of the break in pouring shall be deemed a construction joint. The location of construction joints shall be either as shown on the Drawings or planned in advance and the placing of concrete shall be carried out continuously from joint to joint. The joints shall be perpendicular to the principal lines of stress and at points of minimum shear unless otherwise agreed with the Engineer.

D.2 Where dowels, reinforcing bars or other ties are not indicated on the Drawings, keys shall be made by embedding water-soaked bevelled timbers in workable concrete. The keys shall be sized as detailed on the Drawings or as directed by the Engineer and shall be removed when the concrete has set. When resuming work the surface of the concrete previously placed shall be thoroughly cleaned of dirt, scum, laitance or other soft material with stiff wire brushes and, if deemed necessary by the Engineer, shall be roughened with a steel tool. The surface shall then be thoroughly washed with clean water and pointed with a thick coat of neat cement mortar, after which the concreting shall proceed.

D.3 Expansion joints shall be manufactured and installed in accordance with the Drawings or as approved by the Engineer.

E. Cold Joints

E.1 When the continuous placement of concrete in any structural member is interrupted or delayed for a period long enough for the previously partially placed concrete to take its initial set, the Engineer shall declare such a joint a cold joint in which case the Contractor shall immediately remove the previously partially placed concrete from the forms. No extra payment shall be made for the initial placement or the removal of concrete that is wasted because of a cold joint. The Engineer shall suspend all or any part of the subsequent concrete work until he deems the Contractor has corrected the cause for the cold joint occurrence.

E.2 The Engineer shall, in certain circumstances, allow the Contractor to retain the partially placed concrete and complete the concreting with a subsequent pour. If the Engineer allows a cold joint to be retained, the Contractor shall carry out, at his own expense, some or all of the following measures to the satisfaction of the Engineer before completing the pour:
E.2.1 Laitance shall be removed from the surface of the partially placed concrete without damage to reinforcement and formwork by wire brushing, light tooling or sand blasting as agreed with the Engineer.

E.2.2 Shear keys shall be cut in the partially placed concrete without damage to the reinforcement and formwork. The shape, size and orientation of the shear keys shall be as directed by the Engineer.

E.2.3 The cleaned surface of the partially placed concrete shall be coated with a bonding agent approved by the Engineer, before placing the subsequent pour.

E.2.4 Additives approved by the Engineer to facilitate bonding shall be added to the concrete used for the subsequent pour.

E.2.5 Dowel bars of a type and length to be approved by the Engineer shall be installed in the partially placed concrete using non-shrink cement grout or resin grout as directed by the Engineer. The size and spacing of the dowel bars shall be approved by the Engineer. Their installation shall not damage the reinforcement or formwork.

E.2.6 The partially placed and subsequently placed concrete shall be stressed using prestressing bars of a size and type approved by the Engineer to achieve a level of compressive stress at the interface approved by the Engineer. The method of installing the prestressing bars and type of anchors used shall be approved by the Engineer. Unless otherwise agreed with the Engineer, the drill hole shall be grouted with a cement grout containing expanding additive to the manufacturer’s recommendations.

F. Finishing

F.1 Unless otherwise indicated in the Drawings or agreed by the Engineer, the following classes of finishes, as defined in Paragraph 5.04.05, shall be used for formed surfaces:

F.1.1 Pre-cast parapets, cladding panels, New Jersey Barriers, wall copings and other architectural features: Class F1

F.1.2 Exposed faces of retaining walls, abutments, piers, columns, bridge decks and box culverts not in contact with soil and which can be seen: Class F2

F.1.3 Backs of retaining walls and solid abutments, outer faces of box culverts, faces of abutment columns and bases of bank seats for spill-through abutments, plinths for columns, piers, lighting masts and sign gantries in permanent contact with soil: Class F3

F.1.4 Inner faces of box girders, cellular deck slabs, cellular bases and pile caps not in contact with earth and which are not visible: Class F3
F.1.5 Sides of bases, footings and pile caps permanently below finished ground level: Class F4

F.2 Unless otherwise noted in the Drawings, the following classes of finishes, as defined in paragraph 5.04.5, shall be used for unformed surfaces:

F.2.1 Tops of bases, footings, pile caps and box culverts, which are to be backfilled: Class U1

F.2.2 Top of walls and slab which are to receive coping or tiling: Class U2

F.2.3 Box culvert inverts, apron slabs of box culverts and tops of exposed walls and slabs: Class U3

F.3 Finish to bridge decks that are to receive an approved waterproof system shall initially be finished to Class U1. When the concrete has sufficiently hardened to prevent laitance being worked to the surface the surface shall be floated to produce a uniform surface free from screed marks and exposed aggregate. The surface shall then be textured by brushing or otherwise in accordance with the waterproofing manufacturer's requirements and as agreed with the Engineer. The accuracy of the finished surface shall be such that it does not deviate from the required profile by more than 10 millimetres over a 3 metre gage length or have any abrupt irregularities of more than 3 millimetres.

F.4 Surfaces, other than bridge decks, which are to receive approved waterproofing systems, shall be finished to Class U2, unless otherwise detailed on the Drawings or as instructed by the Engineer.

G. Concrete Cover to Reinforcement

G.1 The concrete cover to reinforcement shall be as shown on the Drawings. If no cover is detailed the cover shall be either the size of the bar or the maximum aggregate size, plus 5 mm, whichever is the greater. In the case of bundled bars, the cover shall be equal to or greater than the size of a single bar of equivalent area of the bundle plus 5 mm.

G.2 Where a surface treatment such as grooved finish or bush hammering cuts into the face of the concrete, the depth of the treatment shall be added to the cover.

G.3 The cover to reinforcement shall take into account the concrete durability under the envisaged conditions of exposure. The minimum cover to reinforcement under such conditions shall be determined by Engineer on site.
H. Tolerances

H.1 In-Situ Construction

H.1.1 Length: The horizontal and vertical dimensions of in-situ concrete members, except cross-sections, shall be within the following tolerances:

<table>
<thead>
<tr>
<th>Length (mm)</th>
<th>Tolerance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 3000</td>
<td>± 3</td>
</tr>
<tr>
<td>3001-4500</td>
<td>± 6</td>
</tr>
<tr>
<td>Vertical lines out of plane</td>
<td>± 5 + 1 for every 3000 out of true line.</td>
</tr>
</tbody>
</table>

H.1.2 Cross-Section: Slab and wall thicknesses and the cross-sectional dimensions of beams, columns and piers shall be within the following tolerances:

<table>
<thead>
<tr>
<th>Member Dimensions (mm)</th>
<th>Tolerance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 500</td>
<td>6</td>
</tr>
<tr>
<td>501-750</td>
<td>10</td>
</tr>
<tr>
<td>Additional for every subsequent 100 mm</td>
<td>±1 mm up to ±20 mm</td>
</tr>
</tbody>
</table>

H.2 Precast Construction

H.2.1 Length: The horizontal and vertical dimensions of precast members, except for cross-sections, shall be within the following tolerances:

<table>
<thead>
<tr>
<th>Length (mm)</th>
<th>Tolerance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 3000</td>
<td>± 2</td>
</tr>
<tr>
<td>3000 and over</td>
<td>± 5</td>
</tr>
</tbody>
</table>

H.2.2 Cross Section: Slab and wall thicknesses and the cross-sectional dimensions of beams, columns and piers, shall be within a tolerance of ± 3 mm.

H.3 Squareness

For in-situ and pre-cast construction the tolerance between the short side and the long side shall be within the following limits:

<table>
<thead>
<tr>
<th>Member Size (mm)</th>
<th>Tolerance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 3000</td>
<td>± 3</td>
</tr>
<tr>
<td>3000 and over</td>
<td>± 6</td>
</tr>
</tbody>
</table>
H.4  Straightness

For in-situ and precast construction the straightness or bow, defined as deviation from the intended line, shall be within the following tolerances:

<table>
<thead>
<tr>
<th>Member Length (mm)</th>
<th>Tolerances (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 3000</td>
<td>± 3</td>
</tr>
<tr>
<td>3000 and over</td>
<td>± 6</td>
</tr>
</tbody>
</table>

H.5  Alignment

The alignment of members shall be within the following tolerances:

Column and piers: 1:400 of column or pier length.
Others: 1:600 of length.

H.6  Flatness

The flatness of a surface, measured with a 1.5 metre straight edge shall be not greater than 6 mm at any point.

H.7  Twist

Twist, measured as the deviation of any corner from the plane containing the other three corners, shall be within the following limits.

<table>
<thead>
<tr>
<th>Member Length (mm)</th>
<th>Tolerance (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 6000</td>
<td>6</td>
</tr>
<tr>
<td>Above 6000</td>
<td>12</td>
</tr>
</tbody>
</table>

5.06.4  MEASUREMENT

The provisions of this Section of the Specification are not measured directly for payment but shall be considered subsidiary to the different classes of concrete described and measured for payment under the provisions of Section 5.01: Concrete and Concrete Mixes and Testing.
SECTION 5.07: PRESTRESSED CONCRETE CONSTRUCTION

5.07.1 SCOPE

The work covered in this Section consists of the requirements for prestressing steel, prestressing components, prestressing equipment and plant and construction requirements for prestressed concrete.

5.07.2 MATERIALS

A. Concrete

Concrete for prestressing shall be in accordance with the requirements of Section 5.01: Concrete Mixes and Testing.

B. Prestressing Steel

B.1 Steel Wire: Steel wire shall comply with AASHTO M204 (ASTM A421), or with BS 5896:1980.

B.2 Stress-Relieved Seven-Wire Strands: Stress-Relieved Seven-Wire Strands shall comply with AASHTO M203 (A416) or with BS 5896:1980.

B.3 High Tensile Steel Bar: High tensile steel bars for prestressed concrete shall comply with AASHTO M275 (ASTM A722) or with BS 4486:1980.

C. Prestressing Components

Prestressing components, such as cable ducts, anchorages and couplers, shall be suitable for the types of cables and bars used and in accordance with the Drawings.

D. Grout

Grout shall be water and cement complying with the requirements of Section 5.01: Concrete Mixes and Testing.

E. Epoxy Bonding Agents for Precast Segmental Construction

E.1 Epoxy bonding agents for match-cast joints shall be thermosetting 100 percent solid compositions that do not contain solvent or any nonreactive organic ingredient except for pigments required for colouring. Epoxy bonding agents shall be of two components, a resin and a hardener. The two components shall be distinctly pigmented, so that mixing produces a third colour similar to the concrete in the segments to be joined and shall be packaged in proportioned, labelled, ready-to-use containers.
E.2 Epoxy bonding agents shall be insensitive to damp conditions during application and shall exhibit high bonding strength to cured concrete, good water resistivity, low creep characteristics and a tensile strength greater than the concrete. The epoxy bonding agents shall function as a lubricant during the joining of the match cast segments, as a filler to accurately match the surface of the segments being joined and as a durable, watertight bond at the joint.

E.3 The physical, chemical and mechanical properties of epoxy bonding agents shall satisfy the recommendations of Federation Internationale de la Precontrainte (FIP) "Proposals for a Standard for Acceptance Tests and Verifications of Epoxy Bonding Agents for Segmental Construction".

5.07.3 DEFINITIONS

A. Prestressing Steel
Steel wire, strand or bars used for prestressing of concrete.

B. Post-Tensioning
The process of tensioning prestressing steel after the concrete has hardened.

C. Pre-Tensioning
The process of tensioning prestressing steel against independent anchorages before the surrounding concrete is placed.

D. Cables and Tendons
Cables and tendons both refer to a bundle of prestressing steel of the same type and size bundled together to be contained within a duct and stressed, individually or collectively, from the same anchorage.

E. Prestressing System
A proprietary system of applying prestress including anchorages, couplers and jacks but not necessarily prestressing steel and cable ducts.

5.07.4 CONSTRUCTION

A. General

A.1 The Contractor shall submit to the Engineer for his approval full details of the proposed prestressing system and suppliers of the basic materials and components. No system shall be incorporated in the Works until approved by the Engineer.
A.2 Prestressing operations shall be carried out only under the direction of an experienced and competent supervisor and all personnel operating the stressing equipment shall have been properly trained in its use. Special precautions shall be taken when working with or near tendons, which have been tensioned or are being tensioned.

B. Cable Ducts

B.1 Ducts shall be maintained in their correct positions during placing of the concrete. Where members are made up of precast units stressed together, the ducts in the joints between the units shall be in perfect alignment and joined securely to allow unimpeded cable threading and pulling and prevent the ingress of the epoxy mortar used for gluing the several units together before stressing. Details of such joints shall first be approved by the Engineer. The tolerance in the location of the sheath shall be plus or minus 3 mm.

B.2 Joints shall be kept to a practicable minimum and each joint adequately sealed against the ingress of any material. Joints in adjacent sheaths shall be staggered by at least 300 mm.

B.3 Ducts shall be kept free of any matter detrimental to the bond between the sheath and the grout and, except for material sealing a sheath joint, between the sheath and the concrete.

B.4 The ends of all ducts shall be sealed and protected until the tendon is threaded through and the stressing operations have commenced. Where sheaths are left exposed to the atmosphere, rust inhibitors shall be used according to the manufacturer's specifications to prevent rusting and corrosion inside the sheaths. Sheaths shall be flushed with clean water before the tendons are grouted. The Contractor is responsible for carrying out these measures at his own expense.

C. Prestressing Steel

C.1 All wires or strands stressed at the same time shall be taken from the same batch. Each cable shall be tagged with its number and the coil number of the steel used.

C.2 Tendons shall not be welded within the length to be tensioned and, unless other methods of cutting are approved by the Engineer, tendons shall be sawn or cropped using an abrasive disc cutter.

C.3 Tendons shall be built into the work strictly in accordance with the system which is being employed.

C.4 Tendons shall not be kinked or twisted and individual wires or strands shall be readily identifiable at each of the members. No strand which has become unravelled shall be used in the Works.
D. Anchorages

D.1 All anchorages shall be approved cast anchorages. Anchor cones, blocks and plates shall be positioned and maintained during concreting so that the centreline of the duct passes axially through the anchorage assembly.

D.2 All bearing surfaces of the anchorages shall be cleaned prior to concreting and tensioning.

D.3 If proprietary forms of anchorage are used, the anchoring procedure shall be strictly in accordance with the manufacturer's instructions and recommendations.

D.4 Any allowance for draw-in of the tendons during anchoring shall be in accordance with the Engineer's instructions and the actual slippage occurring shall be recorded for each individual anchorage.

E. Jacks for Prestressing

E.1 All jacks used for prestressing shall be of the type applicable to the system adopted. The accuracy of the load metering equipment shall be checked to the satisfaction of the Engineer at the start of work each day. Load metering equipment shall be used on all work sites.

E.2 Documentary proof shall be provided confirming that all jacks have been fully overhauled and checked by an agent approved by the manufacturer of the equipment. Each jack shall be accompanied by a test certificate indicating that it has been tested and calibrated by the manufacturer or by an approved testing laboratory up to a load equal to the full capacity of the jack within a period of two years prior to the commencement of prestressing.

E.3 All gauges, load cells, dynamometers and other devices used for measuring the stressing force shall have an accuracy of within plus or minus 1.5 percent. Pressure gauges shall have a capacity and calibrated cell such that the working pressure required to stress the tendons to the fully stated load lies within the central half of the range of the gauge.

E.4 Each gauge shall have a calibration certificate issued by an approved test laboratory. All pressure gauges shall be constructed that they may be calibrated, either directly by an approved testing laboratory or by compressing with a meter gauge, which has itself been calibrated by an approved testing laboratory.

E.5 All pressure gauges shall be re-calibrated before use and at intervals of 14 days during the prestressing operation. The Engineer shall order re-calibration of any pressure gauge at any time should he have reason to suspect damage to or faulty operation of the gauge.
E.6 The accuracy of all prestressing and load measuring equipment shall be checked whenever required by the Engineer. The Contractor shall provide a rig suitable in the opinion of the Engineer, for all checking and calibration of any jacking system consisting of jacks and associated load devices, pressure gauges and dynamometers.

F. Grout for Ducts

F.1 Unless otherwise directed or agreed by the Engineer as a result of grouting trials, the grout shall consist only of ordinary Portland cement and water. The water: cement ratio shall be as low as possible consistent with necessary workability and under no circumstances be higher than 0.45 and not be subject to bleeding in excess of 2 percent after 3 hours, or 4 percent maximum. When measured at 18 °C in a covered glass cylinder approximately 100 mm water shall be reabsorbed after 24 hours.

F.2 Grout shall be mixed for a minimum of two minutes and until a uniform consistency is obtained. The pumpability of the grout may be determined in accordance with the US Corps of Engineers Method CRD-C79; the efflux time of the grout sample immediately after mixing shall not be less than 11 seconds.

F.3 Admixture containing chlorides or nitrates shall not be used. Other admixtures shall be used only with the written permission of the Engineer and shall be applied strictly in accordance with the manufacturer's instructions.

F.4 The design for grout mix shall be tested in accordance with ASTM C49 for longitudinal change. Each design and batch mix shall be tested for vertical dimensional change:

G. Plant for Grouting

G.1 The grout mixer shall produce a grout of colloidal consistency. The grout injector shall be capable of continuous operation with a constant pressure up to 0.7 N/mm² and shall include a system of circulating or agitating the grout while actual grouting is not in progress. All baffles to the pump shall be fitted with sieve strainers of 1.0 mm nominal aperture size to ASTM E11. The equipment shall be capable of maintaining pressure on completely grouted ducts and shall be fitted with a nozzle which can be locked off without loss of pressure in the duct.

G.2 The pressure gauges shall be calibrated before they are first used in the work and thereafter as required by the Engineer. All equipment shall be thoroughly washed with clean water at least once every 3 hours during the grouting operations and at the end of use each day.
5.07.5 POST-TENSION CONSTRUCTION

A. General

A.1 Immediately before tensioning, the Contractor shall prove that all tendons are free to move between jacking points and that members are free to accommodate the horizontal and vertical movements due to the application of prestress.

A.2 Unless otherwise specified, concrete shall not be stressed until it has reached the age at which at least 2 test specimens taken from it attain the specified transfer strength. The test specimens shall be cured in similar conditions to the concrete to which they relate. The Contractor shall cast sufficient specimens to demonstrate that the required strength of the concrete at transfer has been reached.

A.3 Where members consist of jointed elements the strength at transfer of the jointing material shall be at least equivalent to the specified transfer strength of the member.

B. Tension Procedures

B.1 The Contractor shall establish the datum point for measuring extension and jack pressures to the satisfaction of the Engineer.

B.2 The Contractor shall add to the specified forces and allowance where necessary for anchorage friction, wedge pull-in, jack losses and friction due to duct alignment and curvature. The total forces and calculated extensions shall be submitted for the Engineer’s approval before stressing is commenced.

B.3 Immediately after anchoring, the stresses in the tendons shall not exceed 75 percent of their ultimate tensile strength. During stressing the value shall not exceed 80 percent.

B.4 The tendons shall be stressed at a gradual and steady rate until they attain the force and extension specified.

B.5 If the measured extension differs by more than 5 percent from the estimated extension, corrective action shall be taken as directed by the Engineer.

B.6 The force in the tendons shall be obtained from reading on a load cell or pressure gauge and the extension of the tendons measured. Due allowance shall be made for taking up slack in the tendons.

B.7 Stressing shall take place from both ends unless otherwise specified or agreed by the Engineer.

B.8 Where stressing from one end only is permitted, the pull-in at the end remote from the jack shall be accurately measured and appropriate allowance made in the measured extension at the jacking end.
B.9 When the specified tensioning force, including any short-duration overloads, has been applied, the tendons shall be anchored. The jack pressures shall then be released avoiding shock to the tendon anchorages.

B.10 If the pull-in of the tendons at completion of anchoring is greater than that stipulated by the Engineer, tensioning shall be carried out again.

B.11 If it is necessary to cut the tendons to enable the ducts to be grouted, this shall be delayed as long as practicable until the time of grouting. Unless agreed otherwise by the Engineer the tendons shall not be cropped less than 3 days after grouting. Grouting and cropping operations shall not proceed prior to the Engineer’s written approval of the measured extensions.

B.12 The Contractor shall keep full and detailed records of all tensioning operations including the measured extensions, pressure gauge or load cell readings and the amount of pull-in at each anchorage. Copies of these records shall be supplied to the Engineer within 24 hours of each tensioning operation.

C. Grouting Procedures

C.1 Grouting trials shall be undertaken when required by the Engineer. All anchorages shall be sealed before grouting. Ducts shall not be grouted when the air temperature in the shade is lower than 3 °C. Grout shall not be above 32 °C during mixing or pumping; if necessary, the mixing water shall be cooled.

C.2 All ducts shall be thoroughly cleaned using compressed air. Ducts formed without sheathing shall be filled with water at least one hour before grouting. Sheathed ducts shall not be filled with water unless required by the Engineer. Ducts filled with water shall be blown out using compressed air.

C.3 Ducts shall be grouted as soon as practicable after the tendons have been stressed and the Engineer's permission to commence has been obtained. The ducts shall be completely filled with grout. Grout shall be injected in one continuous operation and allowed to flow from the vents until the consistency of the expelled grout is equivalent to that being injected.

C.4 Vents shall be sealed consecutively in the direction of flow and the injection tubes sealed under pressure until the grout has set. The filled ducts shall be protected against shock or vibration for 1 day and the temperature of the grout shall not fall below 3 °C for three days after injection. The level of grout in the injection and vent tubes shall be inspected two days after grouting and made good if necessary.

C.5 The Contractor shall maintain fully detailed records of grouting including the date each duct was grouted, the proportion of the grout and any admixtures used, the pressure, details of any interruptions and any topping up required. Copies of these records shall be supplied to the Engineer within three days of grouting.

C.6 As and when required by the Engineer, the Contractor shall provide facilities and attendance for the radiographic testing of ducts.
5.07.6  PRE-TENSION CONSTRUCTION

A. In pretensioned members where tendons are specified as debonded from the concrete, they shall be covered with sleeves of PVC or other material detailed in the Drawings or approved by the Engineer. The ends of the sleeves shall be taped to the tendon to prevent the ingress of grout.

B. Unless otherwise agreed by the Engineer, tendons shall be stressed in accordance with the requirements of this Specification.

C. Members shall be free to accommodate the horizontal and vertical movements due to the application of prestress.

D. When the concrete has attained the specified strength, the load shall be transferred gradually without severing the tendons. The tendons shall then be trimmed back flush to the face of the concrete and specified protection applied to their ends.

E. All members shall be indelibly marked to show the specified member mark, the production line on which they were manufactured, the date on which the concrete was cast, the load applied and, if they are of symmetrical section, the face which will be uppermost when the member is in its correct position in the Works. The markings shall be so located that they are not exposed to view when the member is in its permanent position.

5.07.7  TESTING

A. Prestressing Steel

A.1 Before approval, at least two samples of the prestressing steel shall be tested at an approved independent laboratory for chemical composition, mechanical strength, relaxation and physical characteristics to the following standards:

- Wires - AASHTO M204 (ASTM A421) or BS5896:1980
- Bars - AASHTO M275 (ASTM A722) or BS4486:1980
- Seven-Wire Strands - AASHTO M203 (ASTM A416) or BS5896:1980.

A.2 Subsequently, the Engineer may require additional samples, selected at random from materials on site, to be similarly tested.

A.3 When compression grips are used, not less than six, selected at random, shall be tested to failure using strands to be used in the Works. The tests shall be conducted in the presence of the Engineer.

B. Anchorages
B.1 Before approval, at least two anchorages shall be tested at an approved laboratory to BS EN 13391:2004. Subsequently, the Engineer may require additional samples, selected at random from materials on site, to be similarly tested.

B.2 For each anchorage type used in the Works, the characteristic value of anchorage efficiency, determined in accordance with BS EN 13391:2004, shall be not less than 90%.

C. Epoxy Bonding Agents

Epoxy bonding agents shall be tested for and satisfy the requirements of all the tests listed in the recommendations of Fédération International de la Précontrainte (FIP) "Proposal for a Standard for Acceptance Tests and Verification of Epoxy Bonding Agents for Segmental Construction" (ISBN 978-0-7211-0892-2).

D. Grout

Where the grouting operation is interrupted or where a blockage, suspected blockage or grout leakage (other than at grout tubes) occurs, the Engineer shall order radiographic tests to be carried out. Strict safety precautions shall be taken during radiography, and the storage, transportation and handling of radioactive materials shall meet current World Health Organisation recommendations.

5.07.8 MEASUREMENT

A. Measurement Items

A.1 Prestressing steel shall be measured by the weight in tonnes for each size and quality of wire, strand or bar installed and accepted.

A.2 In post-tensioning work, the prestressing steel shall be the actual length between the outermost surface of the anchorages except where couplers are used in which case, the prestressing steel shall be assumed to be continuous, without any flares, through the coupler.

A.3 In pre-tension work, the prestressing steel shall be the actual length between the outermost faces of the member.

B. Items Not Measured

B.1 Cable ducts, duct couplers, grout tubes and steel chairs for the correct duct/tendon location shall not be measured for payment but the costs of these items shall be deemed to be included in other (measured) items.

B.2 Anchor blocks for use in pre-tension work shall not be measured for payment but the costs of these items shall be deemed to be included in other (measured) items.
B.3 Prestressing steel used in connection with temporary works is not measured for payment even if such steel is left permanently in the member.

B.4 Epoxy bonding agent used in precast segmental construction shall not be measured for payment.

B.5 Shear keys and location dowels used in precast segmental construction shall not be measured for payment.

B.6 Prestressing steel and anchorages used for applying temporary prestress to glued segments shall not be measured for payment.

B.7 Anchorages and couplers shall not be measured for payment.

C. Inclusion in the Rates

The rates for items entered in the Bill of Quantities shall include for:

- Items not measured.
- Cement, water and additive used in making the grout.
- All prestressing equipment and its calibration.
- Plant, equipment and labour for all stressing and grouting operations, including making good all anchorage pockets as shown on the Drawings or as directed by the Engineer.
- All testing required in the Specifications.

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<tr>
<th>PAY ITEMS</th>
<th>UNIT OF MEASUREMENT</th>
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<tr>
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</tr>
<tr>
<td>(5.7.2) Prestressing strands (state size and type)</td>
<td>Tonne (T)</td>
</tr>
<tr>
<td>(5.7.3) Prestressing bars (state size and type)</td>
<td>Tonne (T)</td>
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</table>
SECTION 5.08: CONCRETE DIAPHRAGM WALLS

5.08.1 SCOPE

The work covered in this Section consists of the preparation of the detailed design, the supply of all equipment and materials required for the casting of concrete diaphragm walls and their testing as and where shown on the Drawings or as directed by the Engineer in accordance with the method statement prepared by the specialist contractor and approved by the Engineer.

All materials and workmanship shall be in accordance with the appropriate British/European Standards, Codes of Practice and other specified standards current at the date of tender.

5.08.2 DEFINITIONS

**Commencing Surface:** The level at which the diaphragm wall equipment first enters the ground.

**Cut-off-level:** The level to which the diaphragm wall is trimmed.

**Element:** An individual component utilized in a particular embedded retaining wall system, e.g. diaphragm wall panel, or primary or secondary pile in a secant wall, which can be constructed in isolation.

**Embedded Retaining Wall (Diaphragm Wall):** Retaining wall with shuttering provided either by the surrounding ground (i.e. cast against soil) or sheet piling.

5.08.3 MATERIALS AND MANUFACTURE

A. **Cast in Situ Concrete Diaphragm Walls**

Unless otherwise shown on the Drawings, concrete shall be Class 310/25 and shall conform to the requirements of Section 5.01 –Concrete Mixes and Testing.

Reinforcement shall conform to the requirements of Section 5.03: Steel Reinforcement and Fixing

B. **Guide Walls**

The design and construction of the guide walls shall be the responsibility of the Contractor and shall take into account the actual site and ground conditions and the equipment to be used on site to ensure stability and avoid undercutting of the guide wall. Guide walls shall be constructed in reinforced concrete or other suitable materials. The minimum depth of any guide wall shall be 1.0 m.
C. **Support Fluid**

Where a support fluid or Bentonite is to be used for maintaining the stability of an excavation the properties and use of the fluid shall be such that the following requirements are achieved:

- continuous support of the excavation
- solid particles are kept in suspension
- the fluid can be easily displaced during concreting
- the fluid does not coat the reinforcement to such an extent that the bond between the concrete and reinforcement is impaired.
- the fluid shall not cause pollution of the ground or groundwater before, during or after use

Details of the type of support fluid, manufacturer’s certificates for the constituents and mix proportions shall be submitted to the Engineer for approval.

All solid additives shall be stored in separate waterproof stores with a raised floor or in waterproof silos which shall not allow the material to become contaminated.

Additives shall be used in accordance with the manufacturer’s recommendations unless otherwise approved by the Engineer. The quality of bentonite shall be in accordance with Publication 163: Drilling Fluid Materials of the Engineering Equipment and Materials Users Association.

The constituents of the fluid shall be mixed thoroughly to produce a homogeneous mix.

The temperatures of the water used in mixing and the support fluid at the time of commencement of concrete placement shall not be less than 5°C.

D. **Additives**

Additives for bentonite shall be limited to the following:

- Sodium carbonate
- Sodium bicarbonate
- Polymers
- Fluidizers: Aquafix, Bentocryl 86, etc.

Additives shall be used preventatively or curatively depending on the particular situation (geology, expected contamination by cement, etc.). The Contractor shall prepare submittal forms for approval by the Engineer for all additives to be used.
E. Panels

The type and dimensions of panels shall be as specified on the Drawings or instructed by
the Engineer. If in the Contractor’s opinion the specified panel types or dimensions are not
adequate to ensure stability, he shall inform the Engineer prior to ordering.

F. Steel Reinforcement

Reinforcement shall conform to the requirement of Section 5.03: Steel Reinforcement.

5.08.4 TESTING

A. The Contractor shall establish a testing regime, including type and frequency of
tests, for the support fluid in accordance with the Specification and with the approval of
the Engineer. The Contractor shall establish a suitably equipped and properly maintained
site laboratory for this purpose and provide skilled staff and all necessary apparatus to
undertake the tests which shall include:

- Density with mud balance
- Viscosity with Marsh cone
- PH value with pH paper
- Sand content with elutriometer
- Filtration potential with filter press

B. These tests shall be carried out several times a day by trained engineers for new
mud, mud for excavation and also prior to concreting. Results shall be analysed by the shift
superintendent who will decide whether to treat the mud with additives or evacuate it.
Daily reports shall be kept on site and copies submitted to the Engineer no later than 24
hours after testing.

C. All tests shall be carried out in accordance with A.P.I. (American Petroleum
Institute) specifications.

5.08.5 STORAGE AND HANDLING

A. The bentonite powder shall be stored in a dry place on the pallets with the plastic
wrapping intact until used. The plastic wrapping shall only be removed on the platform of
the mixing unit.

B. Pallets shall be placed and transported by forklift. The plastic wrapping shall only
be removed at the mixing unit platform immediately prior to use.

C. All reasonable steps shall be taken to prevent the spillage of support fluid on the
site in areas outside of the immediate vicinity of boring. Discarded fluid shall be removed
from site without undue delay. Any disposal of fluid shall comply with the requirements of
current legislation of all relevant authorities.
5.08.6 CONSTRUCTION

A. Guide Walls

A.1 All diaphragm walls shall be constructed utilizing temporary reinforced concrete guide walls. The top of the guide walls shall be maintained 100 mm below ground level in order to facilitate traffic diversions. The external sides of guide walls shall be concreted directly against natural ground and inner faces shall be concreted against vertical formwork.

A.2 Guides walls shall be set out to ensure that any deviation resulting from the excavation of the diaphragm walls (up to 1/200 of excavated height) or setting out up to 20mm out of theoretical, line or guide wall construction up to 25mm out of set out position or the accumulation of them shall not affect the theoretical dimensions of the structures. The distance between guide walls shall be 30 to 50 mm greater that the width of the excavation plant. This tolerance between excavation tool and guide wall shall be located on the outer side of the box to be excavated.

A.3 Every singular point such as corners, change of direction, etc. shall be set out prior to trench excavation. Prior to concreting, the position of the formwork and its verticality shall be checked and approved by the Engineer.

A.4 The guide walls shall be strutted before and after excavation.

A.5 Preliminary trenches shall be excavated to check the presence of unforeseen utilities and thereafter plugged to prevent loss of bentonite slurry during excavation. If bad soil conditions such as organic matter, soft clay, obstructions, etc are encountered during this excavation the soil shall be removed and replaced with lean mix concrete backfill to the underside of guide walls prior to the guide wall installation.

B. Excavation

B.1. Excavation near Recently Cast Panels

Panels shall not be excavated adjacent to other panels which have recently been cast and which contain workable or unset concrete. The Contractor’s planned sequence of construction shall be submitted for approval by the Engineer prior to work commencing.

B.2. Stability of the Excavation

A suitable guide wall, approved by the Engineer, shall be used in conjunction with the method to ensure stability of the strata near ground level until concrete has been placed. During construction the level of support fluid in the excavation shall be maintained within the guide wall or stable ground. In the event of a loss of support fluid from an excavation, the Contractor shall notify the Engineer of his intended action before continuing the work.
B.3. Cleanliness of Base of Excavation

Prior to placing steel or concrete the Contractor shall clean the base of the excavation of as much loose, disturbed and remoulded materials as practical and in accordance with the method of construction and shall wholly or partly remove and replace support fluid while maintaining the fluid head if it does not comply with the Contractor’s stated limits for support fluid levels prior to concreting.

C. Steel Reinforcement

C.1 The number of joints in longitudinal steel bars shall be kept to a minimum. Joints in steel reinforcement shall be such that the full strength of each bar is effective across the joint and shall be made so that there is no detrimental displacement of the reinforcement during the construction of the panel, following the guidance of BS 8110.

C.2 Reinforcement shall be maintained in its correct position during concreting of the panel.

C.3 When reinforcement is made up in cages, the cages shall be sufficiently rigid to enable them to be handled, placed and concreted without damage. If the cage is to be welded together, welding shall be carried out to the requirements of BS 7123:1989. Details of the procedures should be submitted for approval by the Engineer prior to the commencement of work.

C.4 Spacers shall be designed and manufactured using durable materials which shall not lead to corrosion of the reinforcement or spalling of the concrete cover. Details of the method by which the Contractor plans to ensure the correct cover to and position of the reinforcement shall be submitted for approval by the Engineer prior to commencing work.

C.5 The Contractor shall prepare reinforcement detail construction drawings for each panel and these shall be submitted for approval by the Engineer prior to commencing work.

D. Placing Concrete

D.1 General

Unless otherwise shown on the drawings, concrete shall be class 310/25 and shall conform to the requirements of Section 5.01: Concrete Mixes and Testing.

The workability and method of placing of the concrete shall be such that a continuous monolithic concrete panel of the full cross-section is formed and that the concrete in its final position is dense and homogeneous. Concrete shall be transported from the mixer to the position of the panel ensuring that segregation of the mix does not occur.
Before commencement of concreting of a panel, the Contractor shall satisfy himself that the supplier will have available a sufficient quantity of concrete to construct the panel in one continuous operation.

The concrete shall be placed without any interruption that would allow the previously placed batch to have achieved stiffness preventing amalgamation of the two concrete batches.

No spoil, liquid or other foreign matter shall be allowed to contaminate the concrete.

**D.2 Workability of Concrete**

The concrete workability shall be determined using the slump or flow table in accordance with BS 1881. The slump range or target flow for concrete placed through support fluid using a tremie pipe shall be 150 mm or greater or 550 mm ±50 mm respectively.

**D.3 Compaction**

Internal vibrators shall be used to compact concrete within a cast in place panel.

**D.4 Placing Concrete**

The concrete shall be placed through a tremie pipe in one continuous operation. Where two or more pipes are used in the same panel simultaneously, care shall be taken to ensure that the concrete level at each pipe position is maintained nearly equal.

The hopper and pipe of the tremie shall be clean and watertight throughout. The pipe shall extend to the base of the panel and a sliding plug or barrier shall be placed in the pipe to prevent direct contact between the first charge of concrete in the tremie and the support fluid.

The pipe shall at all times penetrate the concrete which has previously been placed with a minimum embedment of 3 metres and shall not be withdrawn from the concrete until completion of concreting. A sufficient quantity of concrete shall be maintained within the pipe at all times to ensure that the pressure from it exceeds that from the support fluid and workable concrete above the tremie base.

The internal diameter of the pipe of the tremie shall be of sufficient size to ensure the easy flow of concrete. It shall be so designed that external projections are minimized, allowing the tremie to pass within reinforcing cages without causing damage. The internal face of the pipe of the tremie shall be free from projections.

The depth of the surface of the concrete shall be measured and the embedded length of the tremie pipe recorded at regular intervals corresponding to each batch of concrete. The depths measured and volumes placed shall be plotted immediately on a graph during the concreting process and compared with the theoretical relationship of depth against volume.
E. Tolerances

E.1 Guide Wall

The finished internal face of the guide wall closest to any subsequent excavation shall be vertical to within a tolerance of 1 in 200 and the top edge of the wall shall represent the reference line. There shall be no ridges or abrupt changes on the face and its variation from its specified position shall not exceed ± 15 mm in any 3 metre section.

E.2 Diaphragm Wall

At cut-off level the maximum deviation of the centreline of each panel from the specified position shall be 15mm. An additional tolerance of 8mm for each 1.0 metre that the cut-off level is below the top of the guide wall shall be permitted.

The exposed wall face and the ends of panels shall be vertical within a tolerance of 1:120 or as directed by the Engineer. An additional tolerance of 100 mm will be allowed for concrete protrusions resulting from cavities formed by overbreak in the ground.

E.3 Recesses

Where recesses are to be formed by inserts in the wall, the vertical tolerance shall be that of the following Clause E.4 and the horizontal tolerance shall be that of the following Clause E.4 plus the horizontal tolerance resulting from Clause E.2.

E.4 Steel Reinforcement

The longitudinal tolerance of the cage head at the top of the guide wall measured along the excavation shall be ± 75mm.

The vertical tolerance of the cage head measured relative to the guide wall shall be +150 / -50mm. The reinforcement shall be maintained in position during concreting of a panel.

F. Temporary Stop-Ends in Diaphragm Panels

A.1 Temporary stop-ends shall be of the length, thickness and quality of material adequate for the purpose of preventing water and soil from entering the panel excavations.

A.2 Each temporary stop-end shall be straight and true throughout. The external surface shall be clean and smooth and free from distortions that may affect panel integrity during removal of the temporary stop-end.

A.3 Stop-ends shall be rigid and adequately restrained to prevent horizontal movement during concreting. The Contractor shall notify the Engineer prior to the removal of each stop-end.
G. Concrete Level

G.1 If the cut-off level for the panel is less than 1 metre below the top level of the guide walls, uncontaminated concrete shall be brought to the top of the guide walls. If the cut-off level is greater than 1m below the top level of the guide walls, concrete shall be brought to 1m above the cut-off level specified, with a tolerance of ± 150 mm. An additional tolerance of + 150mm over the above tolerances shall be permitted for each 1.0 metre of depth by which the cut-off level is below the top of the guide wall.

G.2 Where more than one tremie pipe is used the concrete shall be brought up to 1 metre above the cut-off level specified with a tolerance of ± 250mm.

H. Temporary Backfilling Above Panel Casting Level

After each panel has been cast, any remaining excavation shall be protected and carefully backfilled as soon as possible. Prior to backfilling, panels shall be clearly marked and fenced off so as not to cause a safety hazard.

I. Water Retention

The Contractor shall be responsible for the repair of any joint, defect or panel where, on exposure of the wall visible running water leaks are found. Any leak which results in a flow emanating from the surface of the retaining wall shall be sealed.

5.08.7 WALL INTEGRITY TESTS

A. Loading Tests

The Contractor shall carry out loading tests to evaluate the total load capacity (including friction and end bearing capacity) of the diaphragm walls. Two tests should be carried out on each section as detailed on the Drawings or instructed by the Engineer. The Contractor shall carry out the tests in the presence of the Engineer and prepare a report showing the results of all tests for approval by the Engineer.

B. Sonic Testing

B.1 Sonic test to determine the thickness and integrity of the walls shall be carried out on every tenth panel in the presence of and to the approval of the Engineer. The panels to be tested shall be equipped with 2 no 50/60 mm diameter steel pipes and one 102/114 mm pipe.

B.2 If, in the opinion of the Engineer, a test reveals any weak zone or abnormality in the concrete, a coring through the larger pipe shall be taken as an additional control on the concrete.
5.08.8 MEASUREMENT

Concrete diaphragm walls shall be measured as follows:

A. **Excavation works** shall be measured from the tip to the point where the diaphragm wall is cut away to provide for connection with the structure to the base of excavation as shown on the Drawings. The measured width shall be as detailed on the Drawings. The price is deemed to include:
   - the support fluid or Bentonite
   - establishment and maintenance of the site laboratory and all testing
   - disposal of excavated materials

Excavation works for diaphragm walls shall be measured as unclassified excavation in accordance with Section 2.09: Structural Excavation.

B. **Concrete works** shall be measured by the cubic metre in place and accepted by the Engineer to the on dimensions shown on the Drawings.

Concrete works for diaphragm walls shall be measured in accordance with Section 5.01: Concrete Mixes and Testing.

C. **Waterproofing** shall be measured in accordance with Section 5.15 Waterproofing for Structures.

D. **Reinforcement** shall be measured in accordance with Section 5.03: Steel Reinforcement.

E. **Guide walls** shall be measured by the linear meter including excavation, concrete, reinforcement, formwork, additives, labour and all associated accessories.

F. **Diaphragm wall tests** shall be measured by the number of diaphragm wall tests of each type carried out and completed and for which all specified information and data have been submitted and accepted.

G. **Wall Loading and Integrity (Sonic) Tests** shall be measured by number completed and shall be deemed to include all steel pipes, equipment, accessories, labour and a report showing the results of the tests.

H. **Falsework for Diaphragm Walls**, defective or damaged diaphragm walls, pre-boring, jetting or other methods of facilitating driving, splicing, checks of straightness and tolerances and other ancillary diaphragm wall works shall not be measured for direct payment, but shall be considered as subsidiary works the costs of which will be deemed to be included in the Contract prices for the Pay Items.

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<th>PAY ITEM</th>
<th>UNIT OF MEASUREMENT</th>
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(Consultant)  

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<tr>
<th>Section</th>
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<td>5.08.2</td>
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SECTION 5.09: CONCRETE BRIDGES & ERECTION PROCEDURES

5.09.1 SCOPE

This work covered in this Section consists of erecting bridge structures and decks in conformity with the lines, grades and dimensions shown on the Drawings and in accordance with the Specification.

5.09.2 MATERIALS

The materials shall conform to the requirements of the following sections of the Specification:

Concrete - Sections 5.01: Concrete Mixes and Testing and 5.02: Concrete Handling, Placing and Curing

Forms and Falsework - Section 5.04: Formwork and Falsework

Reinforcement - Section 5.03: Steel Reinforcement

Prestressing - Section 5.07: Prestressed Concrete Construction

5.09.3 CONSTRUCTION

A. Balanced Cantilever Construction with in-Situ Concrete

A.1 General

A.1.1 This work consists of installing temporary bearings, casting concrete units in-situ and setting the superstructure on permanent bearings. The Contractor shall submit complete details and descriptions of all methods, arrangements and equipment which he intends to adopt for approval by the Engineer before construction work commences.

A.1.2 The construction method shall include casting of units, the method of restraining the superstructure during cantilever construction, the method of application of all temporary forces to be used for adjusting horizontal and vertical alignments and placing the structure on permanent bearings, details of work plans and safety measures. The method shall include control methods to ensure the accuracy of alignments of the constructed superstructure and all mechanical devices, labour and materials which are to be used for construction but will not form part of the completed superstructure. Equipment shall not be operated for or placed upon any part of the superstructure at any stage of construction other than that which specifically meets the requirements of total working load per unit. This includes the post-tensioning, jointing, jacking, grouting equipment, materials and other equipment whatsoever.
A.2 Unbalanced Load

A.2.1 During construction the cantilever shall be unbalanced by only one unit at any time and shall be consistent with the holding-down method adopted. A 0.5 kN/m² live load (to allow for men, miscellaneous equipment and stored materials) shall be permissible anywhere on the cantilever. The Contractor shall ensure that this live load limit is not exceeded.

A.3 Construction Schedule

A.3.1 The Contractor shall submit a construction schedule showing the chronological order of every phase and stage of erection and construction of the superstructure for consent by the Engineer. The Contractor shall prepare a table of elevations and alignments required at each stage of construction at the check points listed below:

- The lowest corner at the top surface of any temporary bearing pad, to be used as datum during construction.
- All four corners of the top slabs of the pier units to establish grade and top levels.
- Two points on the longitudinal centreline of each pier unit; one on each end to establish alignment.
- One point on the longitudinal centreline and at least on one corner of each unit along every joint between cast-in-place units to establish elevations and alignments at every stage of construction.

A.3.2 The alignment and elevations of the cantilever shall be checked by the Contractor and the Engineer independently within 1 hour of sunrise on each day that the units are to be cast. The measurements made by the Engineer and the Contractor shall agree to within 5 mm.

A.3.3 The temporary bearing pads at the piers shall be carefully placed. The top surface of these pads shall have the correct elevations, alignments and slopes as required by the working drawings and as established by the procedure described above. Shims shall be used if necessary underneath the pads to accomplish accuracy. The Contractor shall check elevations and alignment of the structure at every stage of construction and maintain a record of all checks, adjustments and corrections made.

A.4 Casting Procedures

A.4.1 Casting of the units shall not begin until approval of the working drawings, calculations and the post-tensioning system has been given by the Engineer.

A.4.2 Sequence: The units shall be match cast beginning with each pier unit. After the pier unit is cast all units on either side of the pier unit shall be cast in order to maintain match casting.
A.4.3 **Set-up:** All materials to be encased within the concrete of the segment shall be properly positioned and supported. Before any concrete is placed, the set-up shall be thoroughly inspected and approved by the Engineer. All ducts shall be located within 5 millimetres of the location given on the approval drawings. The top surface of the units shall be free of depressions or high spots.

A.4.4 Forms shall not be removed until the concrete has achieved the compressive strength specified on the working drawings and has been proved by test cylinders or cubes cured using the same method as the unit. Care shall be taken in removing the forms to prevent spalling and chipping of the concrete.

A.5 **Tolerances**

A.5.1 Formwork for box girder segments shall satisfy the following tolerances:
- Web thickness, +10 mm or -5 mm.
- Thickness of bottom slab +5 mm, but no reduction in depth.
- Thickness of top slab +5 mm, but no reduction in depth.
- Overall width of unit, +/-5 mm.
- Overall depth of unit, +/- 5 mm.
- Length of match cast unit, +/-10 mm but not cumulative and a maximum of 50 mm per span.
- Diaphragm dimensions, +10 mm or -5 mm.

A.5.2 After erection, final post-tensioning, final corrections and adjustments have been completed and the structure has been placed on its permanent bearings, the superstructure shall conform to the grade and alignment shown on the working drawings with due consideration for anticipated creep and superimposed load and dead load deflections within a tolerance of +/-5 mm horizontally and +/- 10 mm vertically.

B. **Glued Pre-Cast Segmental Construction**

B.1 **General**

Where bridge decks are pre-cast in segments and assembled in position for gluing and stressing, the Contractor shall satisfy the Engineer that his proposed construction method will achieve the required standard of workmanship and finish in the time available. The Contractor shall submit details for approval of all his forms, falsework, pre-casting factory and his method of lifting, transporting, assembling, supporting, threading cables, gluing and stressing the pre-cast units before commencement of any work.

B.2 **Epoxy Adhesive**

B.2.1 The epoxy resin adhesive shall be supplied by an approved manufacturer.
B.2.2 Epoxy resin shall be made up and packaged to approved formulations and to specifications agreed by the Engineer.

B.2.3 Epoxy resin material shall be supplied in accurately measured packs with the pack containing the hardener clearly distinguished by both size and labelling. The pack containing the resin shall be large enough to permit the addition of the hardener. Resin and hardener shall be pigmented with dissimilar colours to indicate when even mixing has been completely attained to produce an even grey colour to match the concrete.

B.2.4 Each batch of resin mixed shall be tested for setting by compression and shear tests as described below. No permanent prestress shall be applied to a joint until the epoxy has achieved the required strength. Should this test show that the resin is not setting, the joint shall be broken and the resin removed. Set resin shall be removed by grit blasting. Tests shall be ordered by the Engineer at various times to ensure that the material as mixed complies with the Specification.

B.2.5 All instructions of the manufacturer and/or the formulator shall be submitted to the Engineer for agreement. Such agreed instructions shall be adhered to in all respects.

B.2.6 The Contractor shall arrange and carry out a programme of testing as described in the International Prestressing Federation (FIP) 'Proposal for a Standard for Acceptance Tests and Verification of Epoxy Bonding Agents for Segmental Construction', after consultation with the Engineer on the range of temperatures and work cycles that are to be considered in the tests. The Engineer shall witness the tests.

B.3 Surface Preparation

B.3.1 The interfaces of the units shall be lightly grit blasted before erection to remove laitance. Before applying the epoxy the interfaces shall be clean and free from laitance or any bond-breaking material. Any oil or grease shall be removed. The surface shall have no free moisture.

B.4 Application of Epoxy

Application shall begin immediately after a batch has been mixed. The application shall be to both interfaces to a total nominal thickness of 2 mm using a spatula or by hand. No epoxy shall be applied within 25mm of any duct.
B.5 Preliminary Prestress

B.5.1 Immediately after the interfaces are coated with epoxy, the unit shall be brought into position and the preliminary prestress applied. This prestress shall be just sufficient to start squeezing epoxy resin out of the joint. The amount of prestress required will depend on the formulation of the resin chosen by the Contractor. If this operation is not completed within the contact time the units shall be separated and all epoxy, on both faces, shall be removed with spatulas and an approved solvent. No epoxy shall be applied to the joint until 24 hours after a solvent has been used. The contact time shall be calculated from the manufacturer's instructions. All excess epoxy shall be cleaned off from the outer faces of the webs and the soffit carefully to avoid smearing the concrete face.

B.6 Joining Records

The Contractor shall keep a record of each joint with the following details:
- Joint Number
- Date and Time of jointing
- Batch number of resin and hardener
- Weather conditions (temperature and humidity) continuously recorded
- Results of tests

B.7 Tolerances

Construction tolerances shall be as prescribed for balanced cantilever construction.

C. Precast Beam and Slab Construction

C.1 Manufacture of Prestressed Beams

C.1.1 The details of method of manufacture shall be approved by the Engineer before work commences. No changes shall subsequently be made without the consent of the Engineer.

C.1.2 The Contractor shall inform the Engineer in advance of the date of commencement of manufacture and the dates when tensioning of tendons, casting of members and transfer of stress will be undertaken for the first time for each type of beam.

C.1.3 The Contractor shall submit to the Engineer, not more than 7 days after the transfer of stress, a certificate showing the force and strain in the tendons immediately after anchoring, the strength and age of the test cylinders or cubes cast and the minimum age in hours of the concrete at the time stress was applied to the members. Copies of all 28-day cylinder or cube test results relating to the work shall be retained.
C.1.4 Where the Engineer requires tests to be carried out on beams, the beams to which these tests relate shall not be dispatched to Site until the tests have been satisfactorily completed.

C.2 Storage and Handling of Prestressed Members

Members shall be firmly supported at such bearing positions to ensure that the stresses induced are always less than the permissible design stresses. Members shall be lifted or supported only at the points specified and shall be handled and placed without impact.

C.3 Tolerance in Precast Members

Dimensional Variations shall not exceed the tolerances given below:

- Length +/- 12 mm
- Width and depth:
  - >150 mm +/- 3 mm
  - 150 - 450 mm +/- 5 mm
  - < 450 mm +/- 6 mm
- Bow in the vertical plane 3 mm per 3 metre length up to 9 mm
- Bow in the horizontal plane:
  - < 12 m +/- 6 mm
  - 12 – 18 m +/- 9 mm
  - > 18 m +/- 12 mm
- Difference between longest and shortest dimensions (squareness of beam) in any plane 6 mm
- Twist (measured by the deviation of any corner from the plane containing the other 3 corners) 6 mm
- Flatness (the maximum deviation from a 3 metre straightedge placed in any position on a nominally plane surface) 6 mm

Cover to reinforcement +5 or -0 mm
Prestressing tendons 3 mm in any direction
Dowel holes 3 mm in any direction

C.4 Composite Slab Construction

C.4.1 Where the in-situ concrete deck is cast to act compositely with precast beams, the beams shall be installed to correct line and level, starting from the outermost beam and working inwards progressively. When the beams are laid side by side, before erection the difference in soffit level between adjacent beams shall not exceed 6 mm. Permanent soffit shutters, when used, shall be to the approval of the Engineer and shall be fixed securely to ensure no movement or grout loss during deck concreting.
C.4.2 In-situ concrete deck over any one span shall be poured in one continuous operation and shall be placed in such a sequence that the advancing edge of the freshly deposited concrete over the full width of deck or between longitudinal construction joints is approximately parallel to the deck supports. Lateral displacement of beams shall be prevented during the placing of in-situ concrete.

C.4.3 The width of the in-situ deck shall be within 25 mm of that specified. On curved bridge decks, the in-situ deck may be formed in a series of straights such that the width is within 25 mm of that specified.

D. In-situ Construction

Where bridge decks are constructed in-situ, the details of all forms and falsework shall first be approved by the Engineer. Dimensional variations shall not exceed the following tolerances:

- Length: +/- 12 mm
- Width: +/- 10 mm
- Thickness: +/- 6 mm
- Levels: +10 mm or -0 mm
- Void Location: 6 mm in any direction
- Cover to reinforcement: +/- 5 mm or -0 mm
- Prestressing tendons: 5 mm in any direction

5.09.4 MEASUREMENT

The provisions of this Section of the Specification are not measured directly for payment but shall be considered subsidiary to the different classes of concrete described and measured for payment under the provisions of Section 5.01: Concrete Mixes and Testing.
SECTION 5.10: SHEET PILING

5.10.1 SCOPE

A. The work covered in this Section consists of constructing continuous walls of steel or sheet piles.

B. Steel sheet piling shall be of the section, numbers and lengths as required complete with all necessary corner, junction and special piles as required.

C. Attention is directed to the provisions in “General Safety and Health Regulations” Before performing any pile handling or pile installation operation at any location that is closer than the length of the pile being handled or installed to the edge of any travelled way open to public use, the Contractor shall submit to the Engineer, a detailed plan of the measures that will be employed to provide for the safety of traffic and the public.

5.10.2 MATERIALS

Steel sheet piles shall be of the type and mass specified in the Drawings. Steel sheet piles shall conform to the requirements of AASHTO M 202M (ASTM A 328M), AASHTO M 270M (ASTM A 709M) Grade 345, or to the specifications for “Piling for use in Marine Environments” in ASTM A 690M. Painting of steel sheet piles, when required, shall conform to Section 6.06: Painting of Structures.

5.10.3 DRIVING

A. Sheet piles shall be driven to the specified penetration or bearing capacity indicated on the Drawings or agreed with the Engineer.

B. Sheet piles shall be driven true to the lines and levels shown on the Drawings and in accordance with Table 1 below, unless otherwise instructed by the Engineer. Piles which deviate excessively from the theoretical line shall be extracted, replaced if necessary and re-driven by the Contractor at his own expense.

C. Taper piles shall not be introduced in order to correct piles which have developed a lean, unless the approval of the Engineer is first obtained.

D. Piles which reach refusal before achieving the design penetration shall not be cut off without the approval of the Engineer. A record shall be kept of piles which are cut and the length of the cut off sections.

E. All holes in the piling for rods, anchor bolts, etc., shall be made at site after the piling has been driven to their final levels.

F. After driving, the tops of sheet piles shall be neatly cut off to a straight line at the elevation specified in the Drawings or as directed by the Engineer.
G. Sheet pile walls shall be braced by whalers or other bracing system as shown in the Drawings or directed by the Engineer.

H. When specified in the Drawings, reinforced concrete caps shall be constructed in accordance with Section 5.2: Concrete Handling, Placing and Curing.

Table 1: Tolerances to be Applied to Steel Sheet Piling

<table>
<thead>
<tr>
<th>Dimension to which Tolerance is Applied</th>
<th>Frodingham Profiles</th>
<th>Larssen Profiles</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Width</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Single Piles</td>
<td>± 2%</td>
<td>± 2%</td>
</tr>
<tr>
<td>b) Interlocked Piles</td>
<td>± 3%</td>
<td>± 3%</td>
</tr>
<tr>
<td>2. Thickness of Section</td>
<td>± 10%</td>
<td>± 5%</td>
</tr>
<tr>
<td>3. Weight</td>
<td>± 5%</td>
<td>± 5%</td>
</tr>
<tr>
<td>4. Length</td>
<td>± 200 mm</td>
<td>± 200 mm</td>
</tr>
<tr>
<td>5. Squareness of Cut</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a) Along XX Axis</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td>b) Along YY Axis</td>
<td>10 mm</td>
<td>10 mm</td>
</tr>
<tr>
<td>6. Straightness</td>
<td>2% (pile length)</td>
<td>2% (pile length)</td>
</tr>
<tr>
<td>7. Depth of Section</td>
<td>± 4%</td>
<td>± 4%</td>
</tr>
</tbody>
</table>

5.10.4 EQUIPMENT

A. Driven piles shall be installed with impact hammers that are approved by the Engineer. Impact hammers shall be steam, hydraulic, air or diesel hammers. Impact hammers shall develop sufficient energy to drive the piles at a penetration rate of not less than 3 mm per blow at the specified bearing value.

B. Vibratory hammers shall not be used for installation of piles, unless otherwise shown on the Drawings or specified elsewhere in the Contract Documents.

C. Hammers with an external combustion engine that are not the single action type shall have a transducer that records the ram velocity.

D. Double acting diesel hammers with internal combustion engines shall have a transducer that records bounce chamber pressure.
E. For hammers with no visual method of observing the ram stroke, a printed readout showing hammer energy during driving operation shall be provided for the Engineer by the Contractor.

F. Steam or air hammers shall be furnished with boiler or air capacity at least equal to that specified by the manufacturer of the hammer to be used. The boiler or air compressor shall be equipped with an accurate pressure gauge operated at all times.

G. The valve mechanism and other parts of steam, air or diesel hammers shall be maintained in first class condition so that the length of stroke and number of blows per minute for which the hammer is designed will be obtained. Inefficient steam, air or diesel hammers shall not be used.

H. When necessary to obtain the specified penetration and when authorized by the Engineer, the Contractor shall supply and operate one or more water jets and pumps or furnish the necessary drilling apparatus and drill holes not greater than the least dimension of the pile to the correct depth and drive the piles therein. Jets shall not be used at locations where the stability of embankments or other improvements would be endangered.

I. When it is considered necessary to obtain the specified penetration or to prevent damage to the steel piles or steel shells during driving, the Contractor shall provide special driving tips or heavier pile sections or take other measures as approved by the Engineer.

5.10.5 MEASUREMENT

A. Sheet piling shall be measured by the square metre of the exposed surfaces. No additional measurement shall be made for anchorages and depth of piles below the specified excavated level.

B. The amount of completed and accepted work measured shall be paid for by the square metre of driven piles as approved and accepted by the Engineer and shall be deemed to include full compensation for furnishing all materials, labour, equipment, tools, cutting of excess piles, supplies and all other items necessary for the proper completion of the work.

<table>
<thead>
<tr>
<th>PAY ITEMS</th>
<th>UNIT OF MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5.10.1) Steel Sheet Piling (Each type and size)</td>
<td>Square Metre (m²)</td>
</tr>
</tbody>
</table>
SECTION 5.12: REINFORCED CONCRETE BOX CULVERTS

5.12.1 SCOPE

The work covered in this Section consists of furnishing materials for and the construction of reinforced concrete box culverts and headwalls. All monolithic reinforced concrete box culverts including headwalls and pipe culvert headwalls shall be constructed in conformity to the lines, grades and dimensions shown on the Drawings and in accordance with Section 2.09: Structural Excavation and Backfill, 5.06 Plain and Reinforced Concrete Structures, 5.03 Steel Reinforcement and other pay items in the Bill of Quantities which constitute the complete structure.

5.12.2 MATERIALS

A. The materials shall conform to the requirements of the following sections:
   - Concrete Sections 5.01 & 5.02
   - Steel Reinforcement Section 5.03
   - Formwork and Falsework Section 5.04

B. Concrete classes shall be those prescribed on the relevant Drawings.

5.12.3 CONSTRUCTION

A. Box culverts shall be constructed in sections between expansion joints. Unless shown otherwise on the Drawings or directed by the Engineer, the spacing of expansion joints shall be no greater than 20 metres.

Expansion joints shall also be used at the culvert ends where the culvert meets the wingwalls and apron slabs.

B. Excavation for box culverts located in road embankments shall be carried out using a method shown in the Drawings or approved by the Engineer

C. Excavation for culverts located below original ground level shall be carried out in trenches in accordance with Section 2.09: Structural Excavation and Backfill.

D. Backfilling and compaction shall be carried out in layers not exceeding 200 mm (compacted thickness) and the difference in the levels of backfill on either side of the culvert shall not exceed 500 mm.

E. All concreting shall be carried out in dry conditions. Existing watercourses shall be diverted during the period of construction of the culvert as shown on the Drawings or to the satisfaction of the Engineer.
F. Unless otherwise shown on the Drawings or instructed by the Engineer, the base slab of the box culvert for its entire length shall first be completed before proceeding with the walls and roof slab. Construction joints in the walls shall be located not less than 100mm above the top of the base slab. Unless shown otherwise on the Drawings or directed by the Engineer, the walls and roof slabs shall be concreted in one pour between expansion joints.

5.12.4 MEASUREMENT

The Works prescribed in this Section shall be measured in accordance with the provisions of other relevant sections of the Specifications.
SECTION 5.13 CONCRETE PIPE CULVERTS

5.13.1 SCOPE

The work covered in this Section consists of furnishing materials, and installing and testing pipe culverts for cross drainage as shown on the Drawings.

5.13.2 MATERIALS AND PIPE MANUFACTURE

A. Concrete and Mortar

A.1 Concrete and cement mortar materials shall conform to the relevant requirements of section 5.01: Concrete Mixes and Testing. The type of cement to be used in the manufacture (or in situ construction) of all concrete pipes and in mortar intended for application to pipe joints shall be as shown on the Drawings.

A.2 Unless otherwise shown on the drawings, concrete for pipes shall conform to the requirements of AASHTO M 170M, Class IV Reinforced Concrete Pipes.

A.3 Concrete for cradles, haunching and pipe encasement shall be Class 250/20, unless shown otherwise on the Drawings.

A.4 Concrete bedding for pipes shall be Class 110/25.

B. Reinforcement

Reinforcing steel and steel wire fabric shall conform to the relevant requirements of Section 5.03: Steel Reinforcement.

C. Jointing Materials

C.1 Wherever rubber ring joints are used, the rings or gaskets shall conform to ASTM C 443M (for concrete pipes).

C.2 Either proprietary bitumastic or plastic sealants or flexible elastomeric gaskets or mortar shall be used for concrete pipe jointing, as detailed on the Drawings or approved by the Engineer.

C.3 Where flexible joints are required at pipe joints in concrete bedding, haunching and pipe encasement, they shall consist of compressible fibrous board of 20 mm thickness as approved by the Engineer.
D. Bedding Materials

Granular material used as bedding for pipes shall consist of sand or sandy soil essentially free from clay or organic material, and with 90-100% passing the 4.75 mm (No. 4) sieve and 0-5%, passing the 0.075 mm (No. 200) sieve.

E. Backfill Material

Backfill material around and over pipes shall conform to the relevant requirements of Section 2.09: Excavation and Backfill for Structures unless otherwise shown on the Drawings.

F. Precast Reinforced Concrete Pipe

F.1 Unless otherwise stated on the Drawings, precast concrete pipe for culverts and storm drains shall conform to the requirements of AASHTO M 170M, Class IV, BS 5911 Class H or DIN 4032 Class KW.

F.2 Internal and external pipe surfaces shall be smooth and sound and the pipes correctly dimensioned.

F.3 The manufacture of precast pipe shall conform to the relevant requirements of AASHTO M 170M Class IV, unless otherwise stated on the Drawings.

F.4 Tests shall be performed in accordance with AASHTO T 280 on at least 0.5% of all pipes furnished to determine the external load crushing strength (by the 3-edge bearing method). The minimum D loads producing a 0.3 mm crack and the ultimate load shall be in accordance with Table 4 of AASHTO 170M.

F.5 Absorption tests shall be performed in accordance with AASHTO T 280M on samples from at least 0.5% of all pipes furnished. Sampling procedures and the maximum acceptable absorption shall be as specified in AASHTO M 170M.

F.6 If the Contractor elects to precast pipes on site, details of the casting yard and proposed plant and equipment and methods shall be submitted to the Engineer for approval before precasting commences. The manufacturing process shall conform to all relevant requirements of Section 5.01: Concrete Mixes and Testing, Section 5.02: Concrete Handling Placing and Curing and Section 5.03: Steel Reinforcement.

F.7 Precast pipes represented by sets of test samples which have an average strength less than 85% of the specified strength shall not be incorporated in the Works. Such pipes shall either be destroyed or permanently scored or marked as directed and removed from the Site by the Contractor.
F.8 Precast pipes represented by sets of test samples which have an average strength of 85-90% of the specified strength may be incorporated in the Works provided they are laid on a concrete cradle and haunched. The cradle shall cover the full trench width and extend below the underside of the pipe to a depth of at least 0.25 x the external pipe diameter. The concrete haunching shall extend above the underside of the pipe to a height of 0.5 x the external pipe diameter and be keyed into the surface of the cradle using a method approved by the Engineer.

G. Testing

All pipe and material testing shall be carried out in a laboratory approved by the Engineer.

5.13.3 CONSTRUCTION AND INSTALLATION

A. General

A.1 The Contractor shall take all necessary measures during handling and installation to avoid chipping or other damage to the barrels or ends of the precast concrete pipes.

A.2 Where damage to pipes cannot be satisfactorily repaired to the satisfaction of the Engineer, they shall be replaced at the Contractor's expense.

B. Excavation and Backfilling

All excavation and backfilling for culverts, storm drains, and ducts, including preparation and shaping of trench foundations and pipe bedding, shall be in accordance with the relevant requirements of Section 2.09: Excavation and Backfill for Structures.

C. Pipe Installation

C.1 No pipes shall be installed until the excavations, foundations and bedding have been approved by the Engineer.

C.2 Provision of pre-camber by the Contractor for any pipeline to allow for possible future settlement shall not be attempted unless precise details and instructions in respect of such pre-camber have been issued by the Engineer.

C.3 The inside of each pipe shall be cleaned and the pipe inspected for any major or minor damage immediately prior to laying. Pipes with minor damage shall be reinspected by the Engineer following completion of field repairs and, if approved, shall be installed in the Works. Pipes with major damage shall be rejected and removed from Site.
C.4 All pipes shall be fully and firmly bedded over the entire length of each pipe and shall be laid true to line, level and grade, commencing at the downstream end unless otherwise agreed by the Engineer. Inverts shall be matched to form a continuous line free of appreciable irregularities.

C.5 Bedding for precast concrete pipe shall be shaped to suit the pipe contour and carried up as haunching on both sides to one quarter of the external diameter of the pipe.

C.6 Multiple pipe culverts shall have a clear separation between adjacent pipelines of 300 mm or 0.5 x the external pipe diameter whichever is larger, unless shown otherwise on the Drawings. Backfill between pipe culverts shall be placed and compacted in equal layers not exceeding 150 mm such that the difference in backfill levels on either side of individual pipes does no exceed 150 mm at any time.

C.7 Installed pipes that are subsequently found to be damaged, misaligned, disturbed or displaced by construction traffic, plant or equipment or other causes, at any stage prior to completion of the Works, shall be repaired if practicable and realigned or removed and replaced as directed by the Engineer, at the Contractor's expense.

D. Installation of Precast Concrete Pipes

D.1 Precast concrete pipe shall be installed with the bell (socket) end facing upstream. The pipes shall be fully engaged. Internal gaps of more than 20 mm will not be accepted.

D.2 Pipe joints shall be sealed using cement / sand mortar, bitumastic or plastic sealants, rubber rings or gaskets or elastomeric gaskets. The specific types and methods of joint sealing shall be as shown on the Drawings or approved by the Engineer.

D.3 If pipes are to be sealed with mortar joints, pipe ends shall be cleaned and dampened immediately prior to the mortar application. The joint shall then be sealed completely watertight by filling and neatly finishing with a 1:2 cement / sand mortar of sufficiently stiff workability to remain in position without sagging. Internal mortar joints shall be finished flush with the pipe surface. External surfaces of mortar joints shall be covered with burlap which shall be kept continuously moist for at least 3 days after completion of the joint.

D.4 Sealing of concrete pipe joints using proprietary type joint sealants and gaskets shall be carried out in accordance with the manufacturer's instructions and as directed by the Engineer.

D.5 Where in situ concrete haunching or encasement of precast pipe is required, the specified class of concrete shall be placed, compacted and cured in accordance with the relevant requirements of Section 5.02: Concrete Handling, Placing and Curing. Fibrous board vertical joints shall be constructed in the haunching or encasement at intervals along the line of pipe in accordance with the Drawings or as instructed by the Engineer.
E. Concrete Headwalls, Aprons and Wingwalls

All unreinforced and reinforced concrete headwalls, aprons, endwalls and wingwalls at the ends of pipe culverts shall conform to the relevant requirements of Section 5.06: Plain and Reinforced Concrete Structures.

F. Cleaning and Inspection

F.1 After completion of headwalls, endwalls and wingwalls for culverts, and after backfilling has been completed, the pipelines shall be cleared of all sand, silt and other debris, flushed from end to end with water and left clean and free from obstructions.

F.2 After clearing and cleaning, the larger pipelines (750 mm or larger diameter) shall be inspected by the Engineer from the inside. The Contractor shall provide any required facilities and assistance for such inspections.

5.13.4 MEASUREMENT

A. Single pipe culverts and multiple pipe culverts shall be measured by the linear metre of each size and type furnished, installed or constructed, backfilled, completed, and accepted.

B. Measurement of pipe culverts and pipe arch culverts shall be along the centreline plan length of single pipe culvert or multi-pipe culvert installation. The length measured shall extend from pipe end to pipe end if there is no headwall or end wall, or shall extend between inside faces of headwalls and/or endwalls.

C. Reinforced Concrete Headwalls, Endwalls and Wingwalls shall be measured as prescribed in Section 5.01: Concrete and Concrete Mixes and Testing.

D. Excavation, (except for unsuitable material below bedding) foundation preparation, jointing, bedding and backfilling shall not be measured for direct payment, but shall be considered as subsidiary works the costs of which will be deemed to be included in the Contract prices for associated pay items.

E. Unsuitable foundation material ordered excavated from below the pipe bedding shall be measured for payment as prescribed in Section 2.09: Structural Excavation and Backfill.

PAY ITEMS UNIT OF MEASUREMENT

(5.13.1) Pipe Culvert (Size and Type) Linear metre (m)
SECTION 5.15  WATERPROOFING FOR STRUCTURES

5.15.1  SCOPE

The work covered in this Section consists of furnishing and placing approved waterproofing membranes and damp-proofing courses to external concrete surfaces in contact with soil, furnishing and placing epoxy coatings to internal surfaces of concrete walls, slabs and beds and furnishing and installing waterstops to waterproof construction and expansion joints; all as shown on the Drawings or as directed by the Engineer.

5.15.2  MATERIALS

A.  Asphalt

A.1  Waterproofing asphalt shall conform to the Specification for Asphalt for Dampproofing and Waterproofing, AASHTO M115 (ASTM D449). Type I asphalt shall be used below ground and Type II above ground.

A.2  Primer for use with asphalt in waterproofing shall conform to the Specification for Primer for Use with Asphalt in Dampproofing and Waterproofing, AASHTO M116 (ASTM D41).

B.  Bitumen

B.1  Waterproofing bitumen shall conform to the Specification for Coal-Tar Bitumen for Roofing, Dampproofing and Waterproofing, AASHTO M118 (ASTM D450). Type II waterproofing bitumen shall be provided unless otherwise specified in the Drawings.

B.2  Primer for use with coal-tar bitumen in dampproofing and waterproofing shall conform to the Specification for Creosote for Priming Coat with Coal-Tar Pitch in Dampproofing and Waterproofing, AASHTO M121 (ASTM D43).

C.  Fabric

D. Self-Adhesive Polyethylene Sheeting

Self-Adhesive Polyethylene Sheeting shall be flexible, preformed waterproof membrane comprising strong, high-density polyethylene film with a self-adhesive rubber/bitumen compound and having the following minimum properties:
- Total thickness : 1.5 mm
- Weight : 1.6 kg/m²
- Tensile strength : 42 N/mm²
- Elongation : 210% longitudinally; 160% transversely.
- Tear resistance : 340 N/mm longitudinally; 310 N/mm transversely.
- Puncture resistance: 220 N/65 mm

E. Tar for Absorptive Treatment

Tar for absorptive treatment shall be a liquid water-gas tar that conforms to the following requirements:
- Specific gravity, 25/25°C  1.030 to 1.100
- Specific viscosity at 40°C (Engler), not more than  3.0
- Total distillate, percent by weight, to 300°C, not more than  50.0 %
- Bitumen (soluble in carbon disulphide) not less than  98.0 %
- Water, not more than  3.0 %

F. Tar Seal Coat

Tar seal coat shall conform to the Specification for Tar for Use in Road Construction, AASHTO M52, Grade RTCB-5 (ASTM D490).

G. Joint Fillers

Filler for use in horizontal and vertical joints in waterproofing work shall be a straight refined oil asphalt conforming to the following requirements:
- Flash Point: Not less than 232°C.
- Softening Point: 48.9°C to 54.4°C.
- Penetration: At 0°C, 200 grams, 1 minute, not less than 15.
  At 25°C, 100 grams, 5 seconds, 50 to 60.
  At 46°C, 50 grams, 5 seconds, not more than 300.
- Loss on Heating: At 163°C, 50 grams, 5 hours, not more than 0.5 percent.
- Ductility: At 25°C, 5 centimetres per minute, not less than 85.
- Total Bitumen: (soluble in carbon disulphide): not less than 99.5 percent.

H. Waterstops
H.1 PVC Water Bars shall be extruded PVC, heavy duty, of the types and sizes shown on the Drawings, and complete with junction pieces.

H.2 Copper Water Stops shall be copper sheets of the thickness shown on the Drawings and shall conform to the requirements of AASHTO M138 (ASTM B152).

H.3 Plain Rubber Water Stops shall be formed from stock composed of a high grade compound made exclusively from neoprene, SBR, reinforcing carbon black, zinc oxide, accelerators, anti-oxidants and softeners. This compound shall contain not less than 72% by volume of new plantation rubber. The tensile strength shall be not less than 246 kg/cm², with an elongation at breaking of 550% when tested in accordance with ASTM D412. The unit stresses producing 300% and 500% elongation shall be not less than 77 kg and 198 kg/cm², respectively. The Shore Durometer indication (hardness) shall be between 55 and 65 when tested in accordance with ASTM D676. After 7 days in air at 126 °C (plus or minus 1 °C) or after 48 hours in oxygen at 126°C (plus or minus 1 °C) both at 21kg/cm², the tensile strength and elongation shall not be less than 65% of the original when tested in accordance with ASTM D572.

H.4 Synthetic Rubber Water Stops shall be formed from a compound made exclusively from neoprene, SBR, reinforcing carbon black, zinc oxide, polymerization agents and softeners. This compound shall contain not less than 70 percent by volume of neoprene or SBR. The tensile strength shall be not less than 175kg per square centimetre with an elongation at breaking of 425% when tested in accordance with ASTM D412. The Shore Durometer Indication (hardness) shall be between 50 and 70 when tested in accordance with ASTM D676. After 7 days in air at 126 °C (plus or minus 1 °C) or after 48 hours in oxygen at 126°C (plus or minus 1 °C) and 21kg kg/cm² pressure, the tensile strength shall be not less than 65% of the original when tested in accordance with ASTM D572.

I. Proprietary Waterproofing Systems

Proprietary waterproofing systems shall be bituminous membranes reinforced with layers of suitable reinforcement, bituminous-coated polythene sheet, plasticized polyvinyl chloride sheet, other approved membranes or applications of resinous reinforced coatings. The type to be used shall be defined on the Drawings and shall be chosen according to its location and serviceability. The specific system shall be approved after site trials, should the Engineer decide these to be necessary.

J. Epoxy Coating System

An approved epoxy coating system shall be furnished and applied to the internal concrete surfaces of culverts and open channels as shown on the Drawings or as directed by the Engineer. The thickness of the epoxy coating shall be at least 400 (microns) in accordance with the manufacturer's recommendations.
5.15.3 SURFACE PREPARATION

A. Waterproofing

A.1 All concrete surfaces to be waterproofed shall be reasonably smooth and free from projections or holes which might cause puncture of the membrane. The surface shall be dry to prevent the formation of steam when the hot asphalt or tar is applied. Immediately before the application of the waterproofing, the surface shall be thoroughly cleaned of dust, projecting tying wire and loose material.

A.2 No waterproofing shall be carried out in wet weather or when the temperature is below 4 °C, without special authorisation from the Engineer. Should the surface of the concrete become temporarily damp, it shall be covered with a 2-inch (50mm) layer of hot sand, which shall be allowed to remain in place from 1 to 2 hours or sufficiently long enough to produce a warm and surface-dried condition, after which the sand shall be swept back, uncovering a sufficient surface for commencement of work and the operation repeated as the work progresses.

B. Dampproofing

The surface to which the damp-proofing coating is to be applied shall be cleaned of all loose and foreign material and dirt and shall be dry. If necessary, the Engineer shall instruct the surface to be scrubbed with water and a stiff brush, after which the surface shall be allowed to dry before application of the primer.

5.15.4 INSPECTION, DELIVERY AND STORAGE

A. All waterproofing materials shall be tested before shipment. Unless otherwise ordered by the Engineer, they shall be tested at the place of manufacture and, when so tested, a copy of the test results shall be sent to the Engineer by an agreed chemist or inspection bureau. Each package shall have affixed to it a label, seal, or other mark of identification, showing that it has been tested and found acceptable. The label shall identify the laboratory tests undertaken.

B. After delivery of the materials, representative check samples shall be taken which shall determine the acceptability of the materials.

C. All materials shall be delivered to the work in original containers, plainly marked with the manufacturer's brand or label.

D. Waterproofing and damp-proofing material shall be stored in a dry, protected place. Rolls of waterproofing fabric and membranes shall not be stored on end.
5.15.5 CONSTRUCTION

A. Asphalt and Bitumen Waterproofing Membranes

A.1 Asphalt shall be heated to a temperature between 150 °C and 175 °C and tar for hot application shall be heated to a temperature between 95 °C and 121 °C with frequent stirring to avoid local overheating. The heating kettles shall be equipped with thermometers.

A.2 In all cases, the waterproofing shall begin at the low point of the surface to be waterproofed, so that water will run over and not against or along the laps.

A.3 The first strip of fabric shall be of half-width; the second shall be full-width, lapped the full-width of the first sheet; and the third and each succeeding strip shall be full-width and lapped so that there will be two layers of fabric at all points with laps not less than 5 cm wide. All end laps shall be at least 30 cm.

A.4 Beginning at the low point of the surface to be waterproofed, a coating of primer shall be applied and allowed to dry before the first coat of asphalt is applied. The waterproofing shall then be applied as follows.

A.5 Beginning at the low point of the surface to be waterproofed, a section of 50 cm wide and to the full length of the surface shall be mopped with the hot asphalt or tar and, immediately following mopping, the first strip or half width of fabric shall be carefully pressed into place eliminating all air bubbles. The applied strip and the adjacent section of the surface of a width equal to slightly more than half of the width of the fabric being used shall then be mopped with hot asphalt or tar and a full width of fabric applied, completely covering the first strip, and pressed into place. The second strip and an adjacent section of the concrete surface shall then be mopped with hot asphalt or tar and the third strip of fabric applied, lapping the second strip by at least 5 cm. This process shall be repeated until the entire surface is covered with each strip of fabric lapping at least 5cm over the previous strip. The entire surface shall then be given a final mopping of hot asphalt or tar.

A.6 The completed waterproofing shall be a firmly bonded membrane composed of two layers of fabric and three moppings of asphalt or tar, together with a coating of primer. All layers of fabric shall be separated or covered by layers of asphalt or tar.

A.7 Mopping on concrete shall cover the entire surface with no concrete showing and applied on cloth sufficiently heavy to completely conceal the weave. On horizontal surfaces, not less than 50 litres of asphalt or tar shall be applied for each 10m² of finished work, and on vertical surfaces not less than 60 litres per 10 m² shall be applied. The work shall regulated to ensure that at the close of a day's work, all cloth that is laid shall have received the final mopping of asphalt or tar. All laps shall be thoroughly sealed.

A.8 At the edges of the membrane and at any point where it is punctured by drains or pipes, suitable provision shall be made to prevent water ingress between the waterproofing and the waterproofed surface, to the satisfaction of the Engineer.
A.9 All flashing at kerbs and against girders, spandrel walls, etc. shall be applied using separate sheets overlapping the main membrane by at least 30 centimetres. Flashing shall be closely sealed either with metal counter-flashing or by the embedment of the upper edges of the flashing in a groove full of joint filler.

A.10 Open joints other than expansion joints shall be caulked with oakum and lead wool and then filled with hot joint filler.

A.11 Expansion joints, both horizontal and vertical, shall be provided with sheet copper or lead in "U" or "V" forms in accordance with the Drawings. After the membrane has been placed, the joint shall be filled with hot joint filler. The membrane shall be carried continuously across all expansion joints.

A.12 At the ends of the structure the membrane shall be carried down on the abutments and suitable provision made for all movement.

B. Proprietary Waterproofing Membranes

Proprietary waterproofing membranes shall be installed strictly in accordance with the manufacturer's instructions and shall be laid so that no air is trapped between it and the concrete surface or between successive layers of sheeting. Unless otherwise specified, joints between sheets shall be lapped with end laps of at least 150 mm and side laps of at least 100 mm. The joints shall be arranged so that there are no more than three thicknesses of sheeting and so that water will drain away from the exposed edge.

C. Damage Patching of Waterproofing Membranes

C.1 Finished membranes shall be protected against damage and unnecessary contact. Any damage shall be repaired by patching. Patches shall extend at least 300 mm beyond the outermost damaged portion and the second application shall extend at least 75 mm beyond the first.

C.2 Proprietary waterproofing membranes shall be repaired according to the manufacturer's specifications and as directed by the Engineer.

D. Dampproofing

D.1 Concrete, brick or other surfaces to be protected by dampproofing shall be thoroughly cleaned before the primer is applied. Surfaces shall then be brush- or spray-painted with two or more coats of tar or asphalt for absorptive treatment as indicated on the Drawings or instructed by the Engineer. Dampproofing below ground level shall consist of not less than two coats at an application rate of 0.6 litres per square metre per coat. Above ground level one application of tar or asphalt seal coat shall be applied by brush, at an application rate of 0.5 litres per square metre.

D.2 Paints shall be applied to the areas to be waterproofed only. Any disfigurement of any other parts of the structure by dripping or spreading of the tar or asphalt shall be cleaned at the Contractor’s expense to the Engineer’s approval.
E. Protection of Waterproofing and Dampproofing

E.1 The waterproofing membrane and dampproofing courses shall be protected by a 50 mm course of mortar mixed in the proportion of one part Portland cement and two parts sand, unless otherwise shown on the Drawings. This mortar course shall be reinforced midway between its top and bottom surfaces with wire netting of 0.15m mesh and No. 12 gauge, or its equivalent. The top surface shall be trowelled to a smooth, hard finish true to grade.

E.2 The construction of the protection course shall follow the application of waterproofing within 24 hours.

E.3 Unless otherwise shown on the Drawings or directed by the Engineer, vertical faces either waterproofed or dampproofed shall be protected by a porous concrete block wall of not less than 225mm thickness or a proprietary synthetic sheeting if approved by the Engineer.

F. Water Stops

F.1 Copper Water Stops: Copper sheets for water stops shall be of the width specified and shall be bent to the shapes shown on the Drawings or instructed by the Engineer. The sheet copper in each joint shall be continuous; separate pieces being connected by thoroughly workmanlike soldered joints to form a complete watertight unit. The sheet copper shall be placed to ensure its embedment in the concrete on each side of the joint in the positions shown on the Drawings.

F.2 Rubber Water Stops: Rubber water stops shall be installed in accordance with the details shown on the Drawings. The water stops shall be formed with an integral cross section which shall be uniform within 3mm in width and the web thickness or bulb diameter, within plus 1.5mm and minus 0.75mm. No splices shall be permitted in straight strips. Strips and special connection pieces shall be well cured and all cross sections shall be dense, homogenous and free from all porosity. All junctions in the special connection pieces shall be fully moulded. During the vulcanizing period the joints shall be securely held by suitable clamps. The material at the splices shall be dense and homogenous throughout the cross section. Field splices shall be either vulcanized, mechanical, using stainless steel parts or made with a rubber splicing union of the same stock as the water stop. All finished splices shall demonstrate a tensile strength of not less than 50 % of the unspliced material.

G. Testing

Unless otherwise agreed by the Engineer, at least one site trial application of the waterproofing system shall be carried out to determine the suitability of the surface preparation, method of application and effectiveness of the protective layer. The size of membrane laid shall be not less than 2.0 metres wide and 5.0 metres long.
5.15.6 MEASUREMENT

A. Waterproofing membrane shall be measured by the square metre laid, completed and accepted for different types of waterproofing membranes.

B. Tar or bituminous painting to surfaces permanently in contact with backfilled material shall be measured by the square metre of surface area so painted, irrespective of the number of coats of paint specified.

C. Water stops shall not be measured for direct payment but shall be deemed to be included in the rates for concrete.

D. Protection to waterproofing membrane and dampproofing courses shall not be measured for direct payment but shall be deemed to be included in the rates for waterproofing and dampproofing.

E. Site trials of waterproofing membranes shall not be measured for direct payment but shall be deemed to be included in the rates for waterproofing.

F. The amount of completed and accepted work measured as provided above shall be paid at the unit price bid as specified in the Bill of Quantities; these prices shall be full compensation for furnishing all materials, labour, equipment, tools, supplies and all other items necessary for the completion of the work.

<table>
<thead>
<tr>
<th>PAY ITEMS</th>
<th>UNIT OF MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5.15.1)  Tar or bituminous paint (State type, number of coats)</td>
<td>Square Metre (m²)</td>
</tr>
<tr>
<td>(5.15.2)  Waterproofing Membrane (State type, thickness)</td>
<td>Square Metre (m²)</td>
</tr>
<tr>
<td>(5.15.3)  Epoxy coating to internal surfaces of concrete (State type, thickness)</td>
<td>Square Metre (m²)</td>
</tr>
</tbody>
</table>
SECTION 5.16: STRUCTURAL STEELWORK AND METAL COMPONENTS

5.16.1 SCOPE

A. The work covered in this Section includes all structural steel and castings used in structures and all ferrous and nonferrous metals, except reinforcing bars and metal parapets. Fabrication and construction shall be in accordance with the Specification and the lines, grades, dimensions and designs shown on the Drawings.

B. For details of steel reinforcing bars, refer to Section 5.03: Steel Reinforcement.

C. For details of parapets, refer to Section 5.20: Bridge Parapet and Railings.

5.16.2 MATERIALS

A. Except as otherwise specified, shown on the Drawings, the grades and qualities shall conform to the applicable standards of AASHTO and ASTM:

   A.1 Structural carbon steel shall conform to AASHTO M183M (ASTM A36M).

   A.2 Structural steel for welding shall conform to AASHTO M183M (ASTM A36M).

   A.3 High-strength low-alloy structural steel shall conform to AASHTO M222 (ASTM A588).

   A.4 Rolled, wrought iron shapes and bars shall conform to ASTM A207

   A.5 Wrought iron plates shall conform to ASTM A42

   A.6 Carbon steel forgings shall conform to AASHTO M102 (ASTM A668). Class C1 forgings.

   A.7 Carbon steel castings shall conform to AASHTO M103, (ASTM A27). Grade 70-36 or AASHTO M192M (ASTM A486M), Class 70.

   A.8 Grey-iron castings shall conform to AASHTO M105, (ASTM A48).

   A.9 Malleable-iron castings shall conform to AASHTO M105, (ASTM A48).

   A.10 Rolled copper-alloy bearing and expansion plates shall conform to AASHTO M108, (ASTM B100). Alloy No 1 shall be furnished.

   A.11 High-tensile-strength bolts, including nuts and washers shall conform to AASHTO M164, (ASTM A325) r Grade 8.8 in BS 5950.
A.12 Steel pipe for metal handrail shall conform to ASTM A53, Grade A seamless.

A.13 Aluminium-alloy for metal handrail shall conform to the requirements of Section 5.20: Bridge Parapet and Railings.

A.14 Zinc (hot-galvanized) coatings shall conform to AASHTO M111 (ASTM A123).

A.15 Shop paint and field paint shall be as specified on the Drawings and shall conform to the requirements of Section 6.06: Painting of Structures.

A.16 Gratings, frames, manhole covers and gulley covers shall meet the requirements of Section 5.22: Drainage of Structures and Section 8.05: Manholes, Chambers and Gullies.

5.16.3 CONSTRUCTION

A. Fabrication

A.1 Except as otherwise specified or as shown on the Drawings, all details concerning fabrication shall conform to AASHTO Standard Specifications for Highway Bridges.

A.2 Fabrication of all metal for steel structures and the erection of steel structures shall be in accordance with shop and erection drawings furnished by the Contractor and approved by the Engineer before any fabrication commences.

A.3 Fabrication tolerances shall comply with tolerances stated on the Drawings. The fabrication tolerances for box girder members are shown in Table 5.16.1 below.

**TABLE 5.16.1: STEELWORK FABRICATION TOLERANCES BOX GIRDER MEMBERS**

<table>
<thead>
<tr>
<th>Section</th>
<th>Imperfection</th>
<th>Maximum Tolerance</th>
<th>Length of Gauge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Longitudinal Stiffeners</td>
<td>Lateral departure from line or outstand</td>
<td>2.0 mm</td>
<td>540 mm</td>
</tr>
<tr>
<td>Web and Flange Plates</td>
<td>Departure from flatness along line of longitudinal stiffeners</td>
<td>2.0 mm</td>
<td>Centre to centre distance of diaphragms or transverse stiffeners</td>
</tr>
<tr>
<td></td>
<td>Unstiffened Plate Width</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Up to 400 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Over 400 mm</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Web and Flange Plates</td>
<td>Departure from flatness other than at stiffeners. Gauge transverse</td>
<td>3.0 mm</td>
<td>3.0 mm</td>
</tr>
<tr>
<td>Web and Flange Plates</td>
<td>Departure from flatness other than at stiffeners. Gauge longitudinal</td>
<td>3.0 mm</td>
<td>5.0 mm</td>
</tr>
</tbody>
</table>
A.4 Compliance with tolerances shall be achieved both during and after fabrication before any surface preparation. Remedial measures to remove imperfections shall be approved by the Engineer.

B. Approval of Drawings

B.1 Approval of Contractor's drawings shall not release the Contractor from his responsibilities for work under the Contract. Three copies of each shop and erection drawing prepared by the Contractor shall be submitted to the Engineer for his approval and further copies of corrected or amended drawings shall be submitted, if required, before final approval is given. These drawings shall conform to the Contract Drawings, stress sheets, design specifications and fabrication tolerances. Shop drawings shall include a full and clear set of marking drawings.

B.2 The Contractor shall ensure that all steelwork, including built-in ducts, provides for signs and any other control equipment, prior to submission of his drawings.

B.3 After final approval has been given, the Contractor shall supply to the Engineer a minimum of two further sets of prints and one set of reproducible negatives or an electronic file copy of his final drawings.

B.4 The cost of preparing and furnishing all shop and erection drawings shall be considered as part of structural steel items in the Bill of Quantities and shall not be paid for separately.

C. Substitutions

C.1 The Engineer shall permit substitution if sections shown on the Drawings are not easily obtained. Substitutions of sections shall have equal or greater dimensions than those shown on the Drawings shall be permitted only when approved in writing by the Engineer. No payment shall be made for the additional weight resulting from such substitutions.

C.2 If the Contractor proposes to form individual members or parts of members from two or more pieces using joints additional to those shown on the Drawings then such joints shall be fully detailed on the Contractor’s drawings and submitted to the Engineer, with supporting calculations, for his approval. Full penetration butt welds shall be provided at such joints, unless otherwise approved by the Engineer.

D. Mill Inspection

D.1 The Engineer shall have the right to conduct mill inspections at any time. The Contractor shall furnish the Engineer with three certified copies of the mill orders showing heat numbers of the individual members, together with three certified copies of mill heat test reports showing the properties of each heat number.

D.2 When received on site, each member shall bear the heat number in legible form for the purpose of identification. Acceptance of the material shall be based on approval of the mill heat test reports by the Engineer.
E. Shop Inspection

E.1 General Requirements

E.1.1 The Contractor shall notify the Engineer at least two weeks in advance of commencement of work at the shop for inspection and approval of the facilities. The Contractor shall furnish all facilities for inspection of material and workmanship in the shop and the Engineer shall be allowed free access to all parts of the shop where and when inspection is necessary.

E.1.2 Inspection at the shop by the Engineer shall not relieve the Contractor from any responsibility with regard to defective material or repeating work. The Engineer shall have the authority to reject materials or workmanship which do not comply with the requirements of the Drawings or the Specifications.

E.1.3 Acceptance of any material or furnished member by the Engineer shall not preclude subsequent rejection if later they are found to be defective. Rejected materials shall be replaced promptly and rejected workmanship shall be made good, all at no additional cost to the Contract.

E.2 Inspection of Welds

E.2.1 Radiographic inspection of welds shall be carried out in accordance with the current edition of the Standard Specifications for Welded Highway and Railway Bridges of the American Welding Society. Additional welds to be inspected radiographically will be shown on the Drawings.

E.2.2 Other methods of non-destructive inspection shall be carried out if and as shown on the Drawings.

E.2.3 The Contractor shall secure the services of an organization qualified in the inspection of welds and approved by the Engineer. The Contractor shall bear the costs of this inspection service. Inspection of all welds shall be undertaken only by persons skilled in such inspection and who are acceptable to the Engineer. The Engineer shall review and interpret radiographs and other non-destructive or destructive testing and has the sole authority to accept or reject the inspection or work.

E.2.4 All film and/or other records of weld inspections shall become the property of the Employer.
E.2.5 In the inspection of welds, the presence of any of the following defects shall result in the rejection of the weld:
- Cracks, regardless of length or location
- Overlaps, lack of penetration or incomplete fusion
- Inclusions, including slag, porosity and other deleterious materials less than 1.5 mm in the greatest dimension shall only be allowed if well dispersed and such that the sum of the greatest dimensions of the inclusions in any 25 mm of welded joint does not exceed 9.5 mm and there is no inclusion within 25 mm of the edge of a joint or point of restraint.
- Inclusions, including slag, porosity and other deleterious materials 1.5 mm or larger in the greatest dimension will only be allowed provided that such defects do not exceed the following limits: (where T is the thickness of the thinner plate being welded), for:
  - T up to 19 mm 6.5 mm
  - T 19 mm up to 57 mm T/3
  - T over 57 mm 19 mm
- Any group of inclusions in line that have an aggregate length greater than T in a length of 12T

E.2.6 Defects shall be removed by mechanical means or by oxygen grooving, after which the joints shall be welded again.

F. Galvanizing

Small structural steel or cast steel articles, such as bolts, nuts, washers and similar articles to be galvanized shall be galvanized after fabrication in accordance with the requirements of ASTM A153.

G. Erection

G.1 The Contractor shall be deemed to have satisfied himself before tendering as to the safety and suitability of his proposed methods of site erection. Erection procedures, including any temporary or permanent fastenings, shall at all stages be to the approval of the Engineer. The Contractor shall submit to the Engineer for approval such detailed descriptions and drawings of his proposed procedures, together with supporting calculations, as the Engineer may require. The Engineer's approval of the Contractor's erection procedure shall not relieve the Contractor of his responsibilities for work under the Contract.

G.2 At all stages of erection the structure shall be stable and not liable to excessive oscillations.
G.3 Before delivery to site trial erections of the following completed components shall be carried out and the parts connected for inspection, all as described in AASHTO Standard Specifications for Highway Bridges.
- Every pair of adjacent box girder units as completed
- Every box girder leg unit to base steelwork.

H. Welding

H.1 In addition to the welding of structural steel, all welding shown on the Drawings or ordered by the Engineer shall conform to the Standard Specifications for Welded Highway and Railway Bridges of the American Welding Society.

H.2 Before assigning any welder the Contractor shall provide the Engineer with the names of the welders to be employed on the work together with certification that each of these welders has passed qualification tests using procedures covered in the American Welding Society Standard B3.0, Part 11, or such other qualification test acceptable to the Engineer.

H.3 The Contractor shall order any welder to retake the test when, in the opinion of the Engineer, the work of the welder creates a reasonable doubt as to his proficiency. Tests shall be conducted at no additional cost to the Contract. Recertification of the welder shall be made to the Engineer only after the welder has taken and passed the required retest. Welders shall have passed the qualification tests within the preceding 12-month period.

H.4 All weld sections found defective shall be chipped or cut out to base metal and properly rewelded before proceeding with the work. Should any 2 sections cut from the work of any welder show strengths, under test, of less than that of the base metal, it shall be considered evidence of his poor standard of workmanship and the welder shall be permanently removed from the work. When sections are removed from any part of a structure, the members cut shall be repaired in a neat and workmanlike manner, with joints that develop the full strength of the members and appropriate measures taken where necessary to relieve residual stress, all to the satisfaction of the Engineer and at no additional cost to the Contract.

I. Painting

The number of the paint type and the number of coats of shop paint and field paint shall be as specified on the Drawings. The quality and application shall conform to the requirements of Section 6.06: Painting of Structures.

J. Metal Handrail

Metal handrail, either aluminium alloy or steel shall comply with Section 5.20: Bridge Parapets and Railings and shall be erected in accordance with the Drawings and painted as specified on the Drawings and in accordance with Section 6.06: Painting of Structures.
K. Sealing of Box Members

K.1 All box members, including rolled hollow sections, shall be completely sealed with weld metal as shown on the Drawings except where specific openings are detailed.

K.2 No subsequent drilling of holes in box members, either before or after erection, shall be permitted for fixing of signs or other purposes.

K.3 Unless shown otherwise, ends of members shall be provided with an end plate at least 6 mm thick, fully sealed with weld metal. Duct tubes through box members shall be fully sealed to the members with weld metal.

L. Camber

L.1 Steelwork shall be precambered in order that the specified geometry shown on the Drawings is achieved at a temperature of 15 °C, under full dead load conditions including all signs and other equipment.

L.2 The following general tolerances shall apply to completed steelwork:

- **Line and level:** Plus or minus 5 mm
- **Plumb:** 5 mm per 10 m of height.

M. Spares to Cover Loss of Materials

The Contractor shall provide an adequate number of spares for materials, such as bolts, nuts, washers, packing, cover plates etc, to cover for possible losses. The Contractor shall state on his working drawings the numbers and types of items being ordered in this respect. Payment shall only be made on the basis of the net materials specified, and the Contractor shall allow in his tender for provision of all such spares.

N. Frames, Grates and Covers

Frames, grates and covers that are cast or fabricated shall be placed true to line and grade and shall make full and even bearing on the underlying surface. Frames, grates and covers that are warped or otherwise damaged, in the opinion of the Engineer, shall be rejected and removed from the Site.

O. Metal Parapets

O.1 Parapets shall be securely held in their correct position until all connections and fastenings are complete and post fixings have gained sufficient strength to withstand design holding-down forces. Assessment of strength of the postfixing shall be subject to the Engineer's agreement.

O.2 Finished parapets shall be true to line and level throughout their length.
5.16.4 MEASUREMENT

A. Structural Steel

A.1 Structural steel shall be measured by the kilogram or metric tonne as specified in the Bill of Quantities complete in place as determined from the Engineer's computed weights in accordance with the provisions stated herein.

A.2 For the purpose of payment, all metal fixings, other than metal reinforcement for concrete, such as anchor bolts and nuts, shoes, rockers, rollers, bearing and slab plates, pins and nuts, weld metal, bolts embedded in concrete, shear connectors, plates and shapes for pier protection, water stops and similar metal items shall, unless otherwise specified, be included within the Pay Item for Structural Steel and not be subject to separate measurement.

A.3 The quantity of structural steel to be paid for shall include the weight of any full-size members which are tested to destruction as ordered by the Engineer and which meet the requirements of the Specification. Full-size members who fail to meet the requirements and all members rejected as a result of tests shall not be paid for. All costs incurred in conducting tests shall be borne by the Contractor.

A.4 If the Contractor elects, with the Engineer's permission, to use equivalent sections of greater weight than those shown on the Drawings, he shall bear all additional costs thereof.

A.5 The amount of completed and accepted materials shall be paid for at the unit price bid per kilogram or metric tonne as specified in the Bill of Quantities for structural steel; the price shall be full compensation for furnishing, fabricating, welding, delivering, erecting, radiographic inspection, painting and placing all materials and for all labour equipment, tools and all other items necessary for the proper completion of the work.

B. Metal Handrail

Metal handrail shall be measured for payment under the provisions of Section 5.20: Bridge Parapets and Railings.

C. Manhole Cover

Manhole covers shall be measured for payment under the provisions of Section 8.05: Manholes, Chambers and Gullies.

D. Metal Parapets

Metal Parapets shall be measured for payment under the provisions of Section 5.20: Bridge Parapets and Railings.
E. Other Metal Work

Other metal work shall be measured as specified on the Drawings.

F. Pedestrian Footbridges

F.1 All elements, components, materials, workmanship and procedure for the execution of pedestrian footbridges shall comply with the corresponding Specifications of this Contract.

F.2 Measurement of pedestrian footbridges shall be by the number for each type.

F.3 Payment for pedestrian footbridges shall be at the rate inserted in the Bill of Quantities and shall include for but not be limited to all labour, plant and materials and everything necessary for the proper execution of the work including the design, materials, footbridge deck, reinforced concrete supports, reinforced concrete approach structures, staircases, foundations (including piling if required), formwork, aluminium parapets, expansion joints, bearings, non-slip coating, protection against corrosion, painting, protective coating to all fair faced concrete surfaces, excavation, backfilling, tiling, footbridge drainage, footbridge lighting, temporary works and testing, and all other incidental work in connection with the construction.

G. Computed Weight

G.1 The computed weight shall be obtained by the use of the following rules and assumptions:

- Steel: 7,850 kilograms per cubic metre
- Bronze: 8,720 kilograms per cubic metre
- Cast iron: 7,200 kilograms per cubic metre

G.2 Weights of steel, bronze and cast iron shall be computed on the basis of final dimensions at the unit weights as shown above. The net finished dimensions of the parts as shown on the approved shop drawings shall be used, deducting for copes, cuts, clips and all holes including bolt and rust holes.

G.3 The weight of bolts, including washers, heads and nuts shall be attained by scaled weight measurement methods or by accurate volumetric computations and unit weight.

G.4 The weight of weld metal shall be computed on the basis of the theoretical volume from dimensions of the shop drawing welds at the unit weight of 7,850 kilograms per m³. For ease in computations, weld metal deposited in fillets, joint chamfers and bevels shall be measured but no measurement shall be made for weld metal deposited outside the heat lines of the approved shop drawings. No deductions shall be made for material removed by bevelling or other cutting and subsequently replaced with weld metal.
G.5 No allowance shall be made for erection bolts, temporary laterals, excess field rivets or other similar items.

G.6 Cast steel, cast iron, wrought iron, small structural steel items and bearing devices composed of any single metal or combinations of shall be measured by the kilogram, complete in place, as determined by weighing on an accurate set of scales.

<table>
<thead>
<tr>
<th>PAY ITEMS</th>
<th>UNITS OF MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5.16.1) Structural Steel (Grade)</td>
<td>Tonne (T)</td>
</tr>
<tr>
<td>(5.16.2) Other Metal Works</td>
<td>As defined on the Drawings.</td>
</tr>
<tr>
<td>(5.16.3) Pedestrian Footbridge (each type)</td>
<td>Number (No)</td>
</tr>
</tbody>
</table>
SECTION 5.18 BRIDGE EXPANSION JOINTS

5.18.1 SCOPE

The work covered in this Section consists of furnishing materials for and the installation of expansion joints for bridge decks.

5.18.2 TYPES OF JOINT

A. The joint construction shall be as described on the Drawings and of one of the following types:
   - Buried joint within the bridge deck
   - Elastomeric sealed joints
   - Modular joints using neoprene box or band sections
   - Metallic finger joints

B. Unless otherwise shown on the Drawings, expansion joints shall be the fully waterproof type and shall be to the Engineer's approval. The Contractor shall inform the Engineer well in advance of the type of expansion joint he intends to use and obtain the Engineer's approval of the joint type and manufacturer. The Contractor shall furnish detailed drawings of all the joints and method of assembly and installation procedure for the approval of the Engineer. The Contractor shall ensure that direct site supervision of the first of each type of joint is provided by an experienced technical representative of the manufacturer and thereafter, by competent persons who have been trained in the proper installation of expansion joints. All joints shall be installed in accordance with the manufacturer's recommendations using only materials and tools recommended by the manufacturer. The bedding and nosings of expansion joints shall be considered integral parts of the joint and the joint manufacturer shall supply of all constituent materials required for bedding and nosing of joints at the time of supplying the joint.

5.18.3 MATERIALS

A. Storage of joints, jointing materials, sealants and other associated items shall be in accordance with the Manufacturer's recommendations.

B. The elastomeric, metallic, bituminous, cementitious and resin-based components used in the joint construction shall all be strictly in accordance with the description on the Drawings and to the Manufacturer's specifications.
5.18.4 CONSTRUCTION

A. General

A.1 The positioning of holding down bolts and anchorage systems shall be checked for accuracy and agreed by the Engineer before the casting of the concrete for the joint. Templates or forms shall only be removed with the Engineer's consent. Threaded parts shall be protected, kept clean and protected from corrosion by a grease coating.

A.2 Where the carriageway surfacing is to be removed to accommodate the bridge joint it shall be cut to a clear straight line for the full depth of the surfacing without damage to the concrete substrate or to the waterproofing.

A.3 Before installation of the joint, the concrete surfaces shall be free from laitance and sand, clear and shall comply strictly with the joint Manufacturer's requirements.

B. Nosings

B.1 Construction of nosings at joints using epoxy mortar and epoxy concrete shall be formed under the direction of a competent supervisor experienced in the use of the material. The work shall be carried out in warm, dry weather. The air temperature around the joint shall be not less than 10 °C, which shall be achieved artificially if necessary. Concrete surfaces to which nosings are applied shall be dry, sound and free from laitance. Before application of the primary coat, loose material and dust shall be removed by an air jet tested to ensure that no oil is carried over from the compressor.

B.2 Unless otherwise specified or approved by the Engineer, surfacing shall be carried across the joint and then cut back to accommodate the nosing. The cutting shall be done with a diamond saw to give a clean edge throughout the depth of the material to be removed. Masking material shall be provided to prevent surfacing materials adhering to the deck where nosings are to be formed and shall be located to prevent displacement by the paving machine.

B.3 A primary coat of unfilled epoxy resin composition shall be worked in by brush to all surfaces with which the nosings will be permanently in contact, at a uniform rate of not less than 300 g/m². The mortar shall then be applied as quickly as possible while the primary coat is still tacky.

B.4 The epoxy mortar and epoxy concrete composition shall be approved by the Engineer. Aggregate shall be either silica sand, calcined bauxite or other synthetic or natural aggregate of suitable grading approved by the Engineer. The particle size distribution shall be that which produces a mortar with adequate strength and workability and minimum void volume. Aggregate shall be clean and completely dry. Whichever type of aggregate is used, the epoxy mortar or epoxy concrete constituents shall be thoroughly mixed in a suitable mechanical mixer. The sequence, duration and temperature of mixing shall be in accordance with the manufacturer's instructions.
B.5 The mixed constituents shall be placed in position within the time recommended by the manufacturer, well worked against the primed surfaces and trowelled flush with the adjacent road surface to form a dense mortar to the required profiles. Epoxy mortar shall generally be compacted in courses of thickness not exceeding 50 mm. Where an underlying course is more than one hour old it shall, unless otherwise agreed by the Engineer, be primed with an unfilled epoxy resin priming coat before placing the next course.

B.6 The gap width shall be set, in relation to the prevailing deck temperature, with the joint gap sides parallel as described on the Drawings and within the joint manufacturer's installation instructions. Seals shall remain in compression for the full range of joint movement.

B.7 Expansion joints shall be of uniform width and be accurately set or finished and aligned flush with the finished carriageway surface. Care shall be taken to ensure that metallic components are not bent or deformed during handling and installation.

B.8 The installation process shall strictly comply with instructions given on the Drawings and by the joint manufacturer.

B.9 The expansion joint and waterproofing shall be formed to provide a watertight seal.

B.10 During the placing and hardening of the bedding and bonding materials, movement between the joint and the substrate shall be prevented.

B.11 Before vehicles traffic the joints, temporary covers capable of withstanding vehicular loading shall be provided over expansion joints during and after their installation for a period recommended by the manufacturer or instructed by the Engineer.

5.18.5 MEASUREMENT

A. Bridge expansion joints shall be measured by the linear metre of each joint size (measured by movement range) installed and accepted. The measurement shall be made from the outside face of parapet to the outside face of parapet whether or not the joint types over carriageway, verges and walkways for a particular joint type are similar. No separate measurement shall be made for special kerb units, cover plates over walkways, epoxy mortar bedding and epoxy concrete nosing, but shall be deemed subsidiary to bridge expansion joint construction.

B. The amount of completed and accepted work measured will be paid for at the unit prices bid as specified in the Bill of Quantities, which shall be full compensation for furnishing all materials, labour, equipment, tools, supplies and all other items necessary for the proper completion of the work.
<table>
<thead>
<tr>
<th>PAY ITEMS</th>
<th>UNIT OF MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5.18.1) Buried expansion joint, movement range (   )</td>
<td>Linear Metre (m)</td>
</tr>
<tr>
<td>(5.18.2) Elastomeric (waterproof) expansion joint, movement range (   )</td>
<td>Linear Metre (m)</td>
</tr>
<tr>
<td>(5.18.3) Modular expansion joint with neoprene insert, movement range (   )</td>
<td>Linear Metre (m)</td>
</tr>
<tr>
<td>(5.18.4) Metallic finger expansion joint with neoprene insert, movement range (   )</td>
<td>Linear Metre (m)</td>
</tr>
<tr>
<td>(5.18.5) Metallic finger expansion joint no insert, movement range (   )</td>
<td>Linear Metre (m)</td>
</tr>
</tbody>
</table>
SECTION 5.19 BRIDGE BEARINGS

5.19.1 SCOPE

A. The work covered in this section consists of furnishing testing and installing elastomeric and replaceable metal bridge bearings as shown on the Drawings or as directed by the Engineer.


5.19.2 DEFINITIONS

A. Elastomer: A compound containing natural or chloroprene rubber with properties similar to those of rubber.

B. Roller Bearing: A bearing consisting essentially of one or more steel rollers between parallel upper and lower steel plates.

C. Rocker Bearing: A bearing consisting essentially of a curved surface in contact with a flat or curved surface and constrained to prevent relative horizontal movement. The curved surfaces may be cylindrical or spherical. Rocker bearings permit rotation by rolling of one part on another.

D. Knuckle Bearing: A bearing consisting essentially of two or more members with mating curved surfaces. The curved surfaces may be cylindrical or spherical.

E. Leaf Bearing: A bearing consisting essentially of a pin passing through a number of interleaved plates fixed alternately to the upper and lower outer bearing plates.

F. Sliding Bearing: A bearing consisting essentially of two surfaces sliding one on the other.

G. Elastomeric Bearing: A bearing comprising a block of elastomer that may be reinforced internally with steel plates.

H. Laminated Bearing: An elastomeric bearing reinforced with steel plates.

I. Plain Pad Bearing: An unreinforced elastomeric bearing.

J. Strip Bearing: A plain pad bearing for which the length is at least ten times the width.

K. Pot Bearing: A bearing consisting essentially of a metal piston supported by a disc of unreinforced elastomer that is confined within a metal cylinder.
5.19.3 MATERIALS

A. Steel

A.1 Weldable structural steel shall comply with AASHTO M270 (ASTM A709) unless specified otherwise on the Drawings.

A.2 Steel casting shall comply with AASHTO M192M (ASTM A486M) unless specified otherwise on the Drawings.

A.3 Stainless steel shall comply with ASTM A240 Type 304 unless specified otherwise on the Drawings.

A.4 Cast iron shall comply with AASHTO M105 (ASTM A48) unless specified otherwise on the Drawings.

B. Polytetrafluoroethylene (PTFE)

B.1 Unfilled PTFE shall be pure virgin PTFE without any addition of regenerated materials or fillers and shall meet the requirements of ASTM D1475. The mechanical properties of unfilled PTFE shall be:
- Tensile strength: ASTM D1457 (20N/mm² minimum)
- Elongation at break: ASTM D1457 (200% minimum).

B.2 The composition of filled PTFE shall be such that its coefficient of friction is not more than twice the coefficient of friction of pure PTFE when measured under the same conditions.

C. Lubrication Cavities

C.1 Lubricant retention cavities in PTFE shall comply with the following requirements:
- The plan area of the cavities shall between 10% and 30% of the total PTFE bearing surface including the area of the dimples or grooves.
- The volume of the cavities shall not be less than 3% or more than 20% of the volume of PTFE including the volume of cavities. Only the volume above the top of the recess shall be considered if the PTFE is confined.
- The depth of the cavities shall not exceed half the thickness of the PTFE sheet, or in the case of confined PTFE, the height of its projection from the top of the recess.

C.2 The temperature for hot pressing of cavities shall not exceed 200°C.
C.3 Lubricants

Lubricants for use with PTFE sliding surfaces shall be compounded for long life and to retain their properties within the temperature range to which the bridge is subject and shall not affect the constituent parts of the bearings.

C.4 Adhesives

Adhesives for bonding PTFE to backing plates shall be epoxy resins meeting the requirements of U.S. Federal Specification MMM-A-134. They shall be resistant to the action of lubricants, atmospheric and biological agents and temperatures to which the bearing may be subjected.

D. Elastomers

D.1 Elastomers used in the manufacture of bridge bearings shall contain either natural rubber or chloroprene rubber as the raw polymer, and shall have a hardness in the range of 45 IRHD to 75 IRHD. No reclaimed or ground vulcanized rubber shall be used.

D.2 Elastomeric bridge bearings shall meet the requirements of ASTM D4014 "Standard Specifications for Plain and Steel-Laminated Elastomeric Bearings for Bridges".

E. Other Materials

E.1 Bronze Bearing Plates

Bronze bearing plates shall conform to the Specification for Bronze Castings for Bridges and Turntables, AASHTO M107 (ASTM B22). Alloy 911 shall be furnished unless otherwise specified in the drawings.

E.2 Rolled Copper-Alloy Bearing Plates

Rolled copper-alloy bearing plates shall conform to the Specification for Rolled Copper-Alloy Bearing and Expansion Plates and Sheets for Bridge and Other Structural Uses. AASHTO M108 (ASTM B100), Alloy No. 510 or No. 511 shall be used unless otherwise specified.

E.3 Metal Powder Sintered Bearing Plates

Metal powder sintered bearing plates shall conform to the specifications the ASTM B438, Grade 1: Type II or Grade 2: Type I.

E.4 Phosphor Bronze

Phosphor bronze back plates to porous bronzes plate impregnated with PTFE resins shall conform to ASTM B100 and the porous plate to ASTM B103.
5.19.4 CONSTRUCTION

A. General

A.1 The Contractor shall submit to the Engineer outline details of all bearings, which he proposes to use in the Works. These details shall include the name of the bearing manufacturer, bearing types and typical drawings that will form the basis for approval in principle.

A.2 On obtaining the Engineer's approval in principle, the Contractor shall submit detailed design calculations of each bearing type, detailed drawings of each bearing type, installation drawings (including anchor bolts), material specification and a method statement giving installation procedure and recommended bedding materials for use immediately under and above the bearings. If the Engineer is satisfied with these submissions, he shall give his approval, subject to achieving satisfactory manufacturing tolerances and tests.

A.3 The Contractor shall check and confirm the location of bridge deck jacking points for the future replacement of bearings. The fixing arrangements for all metal bearings shall enable the bearings to be replaced without the need for cutting into the bridge deck, bridge pier or abutment.

A.4 Bearings shall be installed in accordance with the manufacturer's instructions by competent persons who have been trained in, and have experience of, similar bearing installation.

A.5 Bearings shall not be dismantled. Any transit bolts, straps or other temporary fixing shall not be removed until the bearing is fixed in its final position and the structure immediately above the bearing is in place. All transit bolts, straps or other temporary fixings shall then be removed.

A.6 Bearings, which incorporate low friction material, such as PTFE, shall not be opened up to expose the surface of the low friction material. Should this happen accidentally, bearing surfaces are to be cleaned and regreased and reassembled as required by the manufacturer and to the satisfaction of the Engineer.

A.7 All bearings shall be set horizontally in both directions and all bearings shall be positioned so that the inscribed longitudinal axis is parallel to the structure axis at the point of support, unless otherwise noted in the Drawings or directed by the Engineer.
A.8 All metal bearings shall have positive fixings so that the bearing is subsequently removable without excessive jacking. Horizontal forces shall be transferred from the superstructure to bearings and from the bearings to supports by means of shear keys or fixing bolts. Where pre-cast segmental deck construction is used and it is not possible to use positive fittings for the top bearing plates during construction, the top bearing plates shall be temporarily fixed to the deck by epoxy injection. The epoxy used, the method of injection and strength of the fixing shall be to the approval of the Engineer and shall be subject to laboratory and field tests.

A.9 Preset and orientation angles for bearings shall be marked on each bearing by the manufacturer before shipment to site.

A.10 The Contractor shall ensure that any devices such as steel packs used to hold bearings level whilst being fixed shall be removed so that the bearing seats only on its dry pack mortar bedding.

A.11 Metal bearings shall be set in position on steel to within ± 5mm of the specified level. The location of wedges beneath the bearings shall be agreed with the bearing manufacturer prior to installation.

A.12 The gap between the underside of bearing and sub-structure shall be filled with epoxy mortar which shall have a minimum 28-day cylinder strength of 310 kg/sq. cm and the resulting voids filled with an approved epoxy mortar. Construction of the bridge superstructure may then proceed. The supporting falsework and formwork of the bridge superstructure shall not be removed nor permit the transfer of load to the bearings prior to removal of the temporary supporting wedges.

A.13 Bearings shall be maintained in their correct position during placing of the bridge deck. Mating surfaces of bearings shall be kept free from contamination and after the deck has been completed each bearing and the area around it shall be left clean and tidy, to the satisfaction of the Engineer.

B. Steel Elements

B.1 Finished Surfaces

Metal-to-metal contact surfaces within bearings shall be prepared either by machining or fine grinding. Machining shall be carried out after welding has been completed. Machining of rolling contact surfaces of roller bearings or sliding contact surfaces shall be carried out only in the principal direction of movement. Abrasive materials shall be removed from finished surfaces and cleaned with a degreasing agent. Finished surfaces shall be protected from contamination and/or mechanical damage. Surfaces that are to be in contact with grout or bedded on a suitable material may be left unmachined.
B.2 Bolts and Bolt Holes

Bolt holes shall be drilled or reamed. Where specified on the Drawings or required by the Engineer, bolts or screws shall be a vibration resistant type. Taper washers of the correct angle of taper shall be provided under all heads and nuts bearing on bevelled surfaces.

B.3 Welding

B.3.1 General: Welding procedures shall ensure minimize distortion of the bearing components and to avoid damage to finished work and bonded materials. Welding shall comply with the provisions of AASHTO/AWS D.1.5.88 Bridge Welding Code - 1988.

B.3.2 Stainless Steel: Welding of stainless steel sheet to a mild steel backing plate shall be by an inert gas-shielded metal-arc or tungsten inert gas metal-arc process.

B.4 Fixing of Stainless Steel Sheet

B.4.1 Welding: The weld attaching the stainless steel to its backing plate shall be continuous to prevent ingress of moisture and shall be clean, sound, smooth, uniform, without overlaps and properly fused.

B.4.2 Mechanical Fixings with Peripheral Seals: Where a mechanical fixing is augmented by peripheral sealing, the backing plate shall be completely protected against corrosion by painting prior to the fixing of the stainless steel sheet. A continuous flexible seal shall be provided around the periphery of the stainless steel.

B.4.3 Bonding: The stainless steel sheet shall be bonded over its entire area.

B.4.4 Stainless Steel Mating Surface: Stainless steel mating surfaces shall be 20-gauge minimum thickness with a surface finish of less than 500 micrometres. Stainless steel mating surfaces shall be polished or rolled as necessary to meet the friction requirements of this Specification.

C. Bonding of PTFE

Where PTFE sheets are to be epoxy bonded, one side of the PTFE sheet shall be factory treated by an approved manufacturer by the sodium naphthalene or sodium ammonia process.

D. Interlocked Bronze and Filled PTFE Structures

An interlocking bronze and filled PTFE structure consisting of a phosphor bronze plate with a 25mm thick porous bronze surface layer impregnated with a lead PTFE compound. The overlay of compounded PTFE shall not less than 0.3mm thick.
E. PTFE Metal Composite

PTFE metal composite shall consist of virgin PTFE moulded on each side and completely covering an 8mm perforated stainless steel sheet.

F. Forming of Elastomeric Bearings

F.1 Plain Pad Bearings and Strip Bearings: Plain pad bearings shall either be moulded in one piece or comprise single pieces cut from previously moulded strips or slabs. Cutting by the manufacturer shall produce a smooth surface without injurious heating of the elastomer.

F.2 Laminated Bearings: A laminated bearing shall be moulded as a single unit under pressure and heat.

F.3 Spacers in Moulds: When spacers are used in moulds to ensure correct cover to outer plates, they shall comply with the following requirements:
- The resulting exposed steel surfaces shall eventually be covered when the bearings are installed in the bridge structure.
- The spacers shall be located with a minimum distance of 10mm from the reinforcing plate edge to the edge of the spacer.
- The size of the hole left at the surface of the bearing shall not exceed 10mm diameter.
- The minimum practical number of spacers shall be used to ensure the correct location of plates but the total area of spacers shall not exceed 3% of the bearing compression area.

G. Final Assembly and Clamping

After final factory inspection and acceptance of the various parts of the finished bearing they shall be assembled and clamped together. Sliding and roller bearings shall be preset at the time of fixing the clamping devices. All deleterious materials shall be excluded from sliding and other contact surfaces.

H. Marking

Completed bearings shall have the supplier's name (or trade mark) and a serial number indelibly marked thereon. The serial number shall be unique to enable other bearings manufactured at the same time to be traced through the production control records should the need arise. The serial number shall be visible after installation of the bearing in the structure. The top of each bearing shall be clearly marked and the size and direction of preset, if any, and the direction of installation shall be indicated.
5.19.5 TOLERANCES

A. Definition

A.1 Standard Tolerances

Tolerances for flatness, roundness, cylindricity, profile of a surface, parallelism, squareness and position shall be in accordance with the descriptions and illustrations given in BS EN ISO 5458:1999.

A.2 Size

Tolerances for size shall be taken to be variations from the nominal dimensions. They shall be used to control the overall dimensions of components with respect to length, thickness, height and diameter.

A.3 Fit

Tolerances for fit relate to clearance and shall be taken as the difference between the sizes of an element and the hole in which it fits, where this difference is positive.

A.4 Surface Roughness

Surface roughness shall be taken as the arithmetical mean deviation Ra defined in and measured in accordance with BS 1134-1:1988.

B. Overall Dimensions of Assembled Bearings

B.1 General

Overall dimensions of assembled bearings shall be within the tolerances given in Table 5.19.1

**TABLE 5.19.1 TOLERANCES ON OVERALL SIZE**

<table>
<thead>
<tr>
<th>Type of Bearing</th>
<th>Overall Plan Dimensions</th>
<th>Overall Thickness or Height</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elastomeric</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Up to and including 20mm thickness or height</td>
<td>+ 6/-3mm</td>
<td>± 1mm</td>
</tr>
<tr>
<td>Above 20mm thickness or height</td>
<td>+ 6/-3mm</td>
<td>± 5%</td>
</tr>
<tr>
<td>Other than Elastomeric</td>
<td>± 3mm</td>
<td>± 3mm</td>
</tr>
</tbody>
</table>
B.2 Parallelism of Outer Surfaces

When designed to be parallel, the tolerance on parallelism of the upper surface of a bearing with respect to the lower surface of the bearing, as datum shall be 0.2% of the diameter for surfaces circular in plan and 0.2% of the longer side for surfaces rectangular in plan.

C. Dimensions of Bearing Parts

C.1 Roller Bearings

C.1.1 General: The tolerance on flatness for roller plates measured in any direction shall be 0.025mm for lengths up to and including 250mm and 0.01% of the length, in the direction of measurement, for lengths above 250mm. The surface roughness Ra of rolling surfaces shall not exceed 0.8 µm.

C.1.2 Cylindrical Rollers: The tolerance on cylindricity shall be 0.025mm. The tolerance on sizes of single rollers with respect to their nominal diameter shall be +0.5mm and -0.0mm. The tolerance on sizes of multiple rollers with respect to their nominal diameter shall be +0.08mm and -0.0mm.

C.1.3 Non-cylindrical Rollers: Curved surfaces shall have a profile of surface tolerance of 0.3% of the intended radius. The tolerance on size with respect to the height at the centreline of the bearing shall be +0.5mm and -0.0mm. The tolerance on parallelism between the chord line joining the ends of the top rolling surface to the chord line joining the ends of the bottom rolling surface at datum shall be 1mm. The tolerance on squareness between the plane passing through the centres of the rolling surfaces at datum and the top and bottom chord lines joining the ends of the rolling surfaces shall be 1mm.

C.2 Rocker Bearings

C.2.1 Steels with Hardness of 300HB and Over: For steels with a hardness not less than 300HB, determined in accordance with AASHTO T70 (ASTM E10) or BS EN ISO 6506-1:2005, the tolerance on flatness, along the line of contact, for plates mating with rockers shall be 0.075mm for lengths up to and including 250mm, and 0.03% of the length for lengths above 250mm. For rockers, the surface tolerance for the length of the surface over which contact can occur shall be 0.025mm. The surface roughness Ra of rocking surfaces shall not exceed 0.8 µm.

C.2.2 Steels with Hardness Under 300HB: For steels with a hardness less than 300HB, determined in accordance with AASHTO T70 (ASTM E10) or BS EN ISO 6506-1:2005, the tolerance on flatness, along the line of contact, for plates mating with rockers shall be 0.1mm for lengths up to and including 250mm, and 0.04% of the length for lengths above 250mm. For rockers, the surface tolerance for the length of the surface over which contact can occur shall be 0.05mm. The surface roughness Ra of both rocking surfaces shall not exceed 0.5 µm.

C.3 Knuckle Bearings
C.3.1 **Pin and Leaf Knuckle Bearings:** For pins and seatings, the tolerance on cylindricity shall be 0.25mm. For pins up to and including 250mm diameter, the diameter of the pins shall be within a size tolerance of -0.25mm to -0.40mm and the diameter of the seating shall be within a size tolerance of 0.0mm to +0.15mm. For pins exceeding 250mm diameter, the clearance between the pin and the seating shall be not less than 0.4mm and not more than 0.75mm.

C.3.2 **Cylindrical and Spherical Knuckle Bearings:** The tolerances on flatness and profile of surface for cylindrical knuckle bearings and the tolerance on profile of surface for spherical knuckle bearings shall be 0.0002 X h mm or 0.24mm, whichever is the greater, where X is the length of the chord (in mm) between the ends of the PTFE surface in the direction of rotation and h is the projection of the PTFE in millimetres above the top of the confining recess for confined PTFE or the thickness in millimetres for bonded PTFE. The tolerance on size with respect to the radius of the curved surface on the finished bearing shall be 3% of the intended radius. The surface roughness Ra of metal curved surfaces shall not exceed 0.5 µm. Where PTFE forms one of the contact surfaces it shall comply with the appropriate requirements given in 3.4 below.

C.4 **Plane Sliding Bearings**

C.4.1 **PTFE Sheet:** The tolerance on flatness of PTFE sheet shall be 0.2mm where the diameter or diagonal is less than 800mm and 0.025% of the diameter or diagonal where this dimension is greater than or equal to 800mm. On PTFE surfaces made up of more than one piece of PTFE the above conditions shall apply to the diameter or diagonal dimension of the inscribing circle or rectangle around the PTFE. The dimensional tolerances on PTFE sheet shall be as given in Table 5.19.2. The gap between the edge of the PTFE sheet and the edge of the recess in which it is confined shall not exceed 0.5mm or 0.1% of the corresponding plan dimensions of the PTFE sheet, in the direction measured, whichever is the greater. The profile tolerance on the specified projection of PTFE above its confining recess shall be as given in Table 5.19.3. All measurements on PTFE sheet shall be made at a temperature of 20°C to 25°C.

<table>
<thead>
<tr>
<th>Diameter or Diagonal (mm)</th>
<th>Tolerance on Plan Dimension (mm)</th>
<th>Tolerance on Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Recessed PTFE</td>
</tr>
<tr>
<td>&lt; 600</td>
<td>± 1.0</td>
<td>+ 0.5/-0</td>
</tr>
<tr>
<td>600 - &lt; 1200</td>
<td>± 1.5</td>
<td>+ 0.6/-0</td>
</tr>
<tr>
<td>Over 1200</td>
<td>± 2.0</td>
<td>+ 0.7/-0</td>
</tr>
</tbody>
</table>

C.4.2 **Mating Surfaces:** For plane surfaces mating with PTFE, the flatness tolerance in all directions shall be 0.0002Lh mm, where L is the length in millimetres of the PTFE surface in the direction measured and h is the projection of the PTFE in
millimetres above the top of the confining recess, for confined PTFE, or the thickness in millimetres for bonded PTFE. The surface roughness Ra of metal planar sliding surfaces shall not exceed 0.15 µm.

**TABLE 5.19.3: PROFILE TOLERANCES ON PTFE PROJECTION**

<table>
<thead>
<tr>
<th>Maximum Dimension of PTFE (Diameter or Diagonal) (mm)</th>
<th>Tolerance on Specified Projection above Recess (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 600</td>
<td>+ 0.5 / -0</td>
</tr>
<tr>
<td>&gt; 600, ≤ 1200</td>
<td>+ 0.6 / -0</td>
</tr>
<tr>
<td>&gt; 1200, ≤ 1500</td>
<td>+ 0.8 / -0</td>
</tr>
</tbody>
</table>

**C.5 Elastomeric Bearings**

**C.5.1 Parallelism:** The tolerance on parallelism for the axes of reinforcing plates with the base of the bearing as datum shall be 1% of the diameter, for plates circular in plan or 1% of the shorter side, for plates rectangular in plan.

**C.5.2 Size:** The tolerance on size to the plan dimensions of plates for reinforcing elastomeric bearings shall be +0 mm and -3 mm. The tolerance on size to the thickness of the top and bottom covers for laminated elastomeric bearings shall be between +20% and 0% of the nominal thickness, or 1 mm, whichever is the lesser. The tolerance on size with respect to the thickness of an individual inner layer of elastomer in a laminated elastomeric bearing shall be ±20% of its nominal thickness value, or 3 mm, whichever is the lesser. The tolerance on size to the thickness of the side cover for a laminated elastomeric bearing shall be +3 mm and -0 mm.

**C.6 Pot Bearings**

The tolerance of fit between the piston and the pot shall be +0.75 mm to +1.25 mm.

**C.7 Guides**

The surface roughness Ra of metal sliding surfaces shall not exceed 0.5 µm.

**C.8 Fixing Holes in Bearing Plates**

Where required, tolerances on the position for centres of fixing holes shall be as specified or approved by the Engineer.
5.19.6 PROTECTIVE MEASURES

A. Aluminium Alloy Components

Permanently exposed surface of aluminium alloy components shall be degreased and painted as specified or approved by the Engineer. Where aluminium would otherwise be in contact with Portland cement concrete, the former should be suitably protected.

B. Ferrous Components

Exposed parts of iron and steel shall be protected against corrosion as specified or approved by the Engineer.

C. Dissimilar Materials

Measures approved by the Engineer shall be taken to prevent electrolytic action between dissimilar metals in contact by the use of suitable insulation and prevention of moisture penetration.

D. Damaged Areas

Any damaged areas of protective treatment shall be made good to the satisfaction of the Engineer or the damaged parts replaced.

5.19.7 TESTING

A. General

A.1 All testing shall be carried out at approved independent laboratories.

A.2 The Engineer shall attend one or all of the tests. The Contractor shall arrange the dates and times of tests to enable the Engineer to attend the tests. If the Engineer cannot attend a test the Contractor shall, at his own cost, arrange for an independent observer approved by the Engineer, to witness the test.

A.3 A test report in English prepared by the independent laboratory shall be submitted in triplicate. The report shall include photographs and descriptions of the test rigs, instrumentation and all factual data with a comparison of test results with the requirements of the Specification.

B. Material Tests

B.1 The physical and mechanical requirements of all metal components shall be tested for compliance with the Specification.
B.2 PTFE shall be tested for tensile strength and elongation in accordance with ASTM D1457.

B.3 The physical and mechanical properties of elastomers for elastomeric bearings and elastomers used in pot bearings shall be tested according to the standards specified in ASTM D4014 for compliance with the acceptance criteria set out in ASTM D4014.

B.4 The Contractor shall provide the Engineer with sufficient and reliable production test certificates. The Engineer shall determine the extent and nature of independent testing for any or all of the components and instruct the Contractor accordingly.

C. Load Testing of Metal Bearings

C.1 Vertical Load Tests

C.1.1 The vertical load shall be applied in equal increments, of not less than five, up to the specified working load. Each incremental load shall be maintained for 1 to 3 hours as agreed with the Engineer. The load shall then be removed in equal decrements. A second cycle of load increments and decrements shall be applied with the maximum working load held for 30 minutes. The load-deformation graph shall be plotted for both load cycles. At the end of the second load cycle, the bearing shall be dismantled and the bearing surfaces examined.

C.1.2 If the bearing surfaces show no sign of distress, a further two load cycles as described in C.1.1 above shall be carried out with the maximum load in each cycle equal to 1.5 times the specified load.

C.1.3 The period to which the maximum load is to be held shall be determined by the Engineer and shall depend on the slope of the load-deformation graph.

C.2 Friction Tests

Friction tests shall be performed at constant vertical loads of 50 and 80 per cent of the working load. The horizontal load shall be applied to obtain a steady rate of movement of 1 mm per minute to reach a total movement of 30mm or as directed by the Engineer.

C.3 Guide Tests

Guide tests shall be carried out at constant vertical loads of 50 and 100 per cent of the rated load. The horizontal load shall be applied in ten equal increments to a maximum of the designed horizontal load. Two load cycles for each test shall be performed. Where required by the Engineer, electrical strain gauges shall be installed on the base plate at 30 degrees spacing on one quarter of the base plate to measure the stress occurring at the rim/base junctions.

C.4 All steel elements of the bearing load tested shall be tested for mechanical strength and chemical composition and, where rolled steel sheets are used, the
mechanical strength test shall be carried out in the directions of rolling and perpendicular to rolling.

C.5 Sampling

At least one bearing of each type, selected by the Engineer at random, shall be load tested.

D. Load Testing of Elastomeric Bearings

D.1 The sampling and load testing of elastomeric bearings shall be in accordance with ASTM D4014.

D.2 The maximum test load for vertical load, without shear deformation of the elastomer, shall be 2 times the specified vertical load.

D.3 Shear testing shall be carried out at constant vertical loads of 50 and 100 per cent of the specified load.

D.4 The requirements for load testing of elastomeric bearings may be dispensed with if, in the opinion of the Engineer, sufficient production test data exists.

5.19.8 MEASUREMENT

A. Measurement of bridge bearings shall be by the number of each type of bearing installed and completed in place and accepted. Bearings of the same type but of different load capacities shall be measured separately.

B. Bearing tests, installation trials, bedding, nuts and bolts and epoxy injection shall not be measured separately but shall be deemed to be subsidiary to payment for bearings. Where the temporary restraint of a bearing is necessary due to the sequence of deck construction, it shall not be measured separately for payment.

C. The amount of completed and accepted work measured as described above, shall be paid for at the unit prices bid for each type of bridge bearing as specified in the Bill of Quantities. The prices shall be full compensation for furnishing all materials, labour, equipment, tools, supplies and all other items necessary for the proper completion of the Work.

<table>
<thead>
<tr>
<th>PAY ITEMS</th>
<th>UNIT OF MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5.19.1) Steel Bearings (Type and Capacity)</td>
<td>Number (No)</td>
</tr>
<tr>
<td>(5.19.2) Elastomeric Bearing (Type and Capacity)</td>
<td>Number (Nr)</td>
</tr>
<tr>
<td>(5.19.3) Bearing Strip (Type and Capacity)</td>
<td>Linear Metre (m)</td>
</tr>
</tbody>
</table>
SECTION 5.20 BRIDGE PARAPETS AND RAILINGS

5.20.1 SCOPE

The work covered in this section consists of furnishing and installing bridge parapets, railings and noise barriers as and where shown on the Drawings or as directed by the Engineer.

5.20.2 MATERIALS

A. General
Parapets shall be constructed using aluminium alloy, structural steel or reinforced concrete as shown on the Drawings.

B. Aluminium Alloy
Aluminium alloys used for bridge parapets and railings shall conform with the requirements of AASHTO M193 and M219 or BS EN 485 1-4, BS EN 515:1993, BS EN 573 1-4, BS EN 755 1-9, BS EN 12020, BS EN1559-1, BS EN 1676, BS EN1706 and BS EN 1559-4.

C. Structural Steel
Structural steel used for bridge parapets, railings and noise barriers shall conform to the requirements of the Section 5.16: Structural Steelwork and Metal Components. The anchorage system shall be as shown on the Drawings or be of a type approved by the Engineer.

D. Reinforced Concrete
Reinforced concrete used for bridge parapets shall conform to the requirements of the Section 5.01: Concrete, Mixes and Testing, Section 5.02: Concrete Handling, Placing and Curing, and Section 5.06: Plain and Reinforced Concrete Structures. The anchorage system shall be as shown on the Drawings or be of a type approved by the Engineer.

E. Plexiglas Noise Barriers
Plexiglas noise barriers used for noise-control shall conform to the requirements of BS EN ISO 354 and BS EN ISO 140-3:1995.

F. Anchorage System
The anchorage system of parapets, rails and noise barriers shall be so designed that damaged metal posts and rails can be readily replaced without the need for cutting the bridge deck or copings or edge units into which the anchorages are located.
5.20.3 CONSTRUCTION

A. During erection the parapet units shall be securely held in their correct positions until all connections and fixings are complete and the post fixings have gained adequate strength to develop the full holding down moment. The assessment of the adequacy of the post fixing shall be subject to the Engineer's approval. The finished parapets shall be true to line and level throughout their length.

B. The welding of aluminium shall comply with the requirements of BS EN 1011-4:2000. All welding shall be carried out in the factory under a controlled environment. Welding of steel parapet units shall be carried out in the factory or on site in compliance with Section 5.16: Structural Steelwork and Metal Components.

C. Metal bridge parapet posts and rails shall be installed using tools and procedures recommended by the manufacturer and by competent persons who have been trained in the installation of the type of bridge parapets used.

D. The rail and posts of the parapet shall be closed sections, presenting no visible seam welds or exposed bolt heads. The shape and texture of the posts and rails and the protective treatment to be applied shall be as indicated on the Drawings and deviations and/or alterations shall not be permitted.

E. The standard of finish of reinforced concrete parapet units shall conform to the finish of approved units made before main production commences. Where minor blemishes and discolorations occur on production units making good with an approved epoxy mortar compound shall only be permitted with the approval of the Engineer. Units, which are considered unacceptable for use in the works by the Engineer, shall be destroyed. Parapet units shall be installed without cracking or other damage to the concrete unit or its finish.

5.20.4 MEASUREMENT

A. Bridge parapets shall be measured by the linear metre of different types of parapets and railings installed, completed and accepted. Bridge noise barrier shall be measured by the square metre of different type of plexiglass sound control barrier, completed and accepted. No separate measurement shall be made for full scale dynamic testing or any other testing that is required but shall be considered included in the payment item for bridge parapets. Expansion joints, aluminium plates to cover the joint between the median New Jersey barriers on bridge deck, specially fabricated units of posts and rails for nosing areas, special requirements at junctions with transition walls or guard rails, grit blasting to produce the required surface texture, holding down assemblies and stitching concrete shall all be included in the rates for bridge parapets.

B. Payment for completed and accepted work shall the unit rate per linear metre for parapets and per square metre for noise barriers, the price of which shall include for furnishing all materials, labour, equipment, tools, tests, records and all other items for completing the works as specified.
<table>
<thead>
<tr>
<th>PAY ITEMS</th>
<th>UNIT OF MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(5.20.1)  Concrete Bridge Parapet ((state , type))</td>
<td>Linear Metre ((m))</td>
</tr>
<tr>
<td>(5.20.2)  Steel Bridge Parapet ((state , type))</td>
<td>Linear Metre ((m))</td>
</tr>
<tr>
<td>(5.20.3)  Aluminium Bridge Parapet ((state , type))</td>
<td>Linear Metre ((m))</td>
</tr>
<tr>
<td>(5.20.4)  Steel Pedestrian Railings ((state , type))</td>
<td>Linear Metre ((m))</td>
</tr>
<tr>
<td>(5.20.5)  Aluminium Pedestrian Railing ((state , type))</td>
<td>Linear Metre ((m))</td>
</tr>
<tr>
<td>(5.20.6)  Noise Barrier ((state , type))</td>
<td>Square Metre ((m^2))</td>
</tr>
</tbody>
</table>
SECTION 5.21: JOINTS, SEALERS AND FILLERS

5.21.1 SCOPE

This work covered in this Section consists of joint sealing materials and preformed expansion joint filler for use as and where shown on the Drawings or as directed by the Engineer.

5.21.2 MATERIALS: JOINT SEALING COMPOUNDS

A. Hot Type Joint Sealing Compounds

A.1 Composition

This type shall be a mixture of virgin synthetic rubber or reclaimed rubber, or a combination of the two, with asphalt plasticizers. Ground cured rubber scrap shall not be used.

A.2 Physical Requirements

A.2.1 The joint sealing compound, after heating and application, shall form a resilient and adhesive compound capable of effectively sealing joints in concrete against the infiltration of moisture and foreign material through repeated cycles of expansion and contraction. It shall be capable of being brought by heating to a uniform, smooth pouring consistency, free from lumps, and suitable for completely filling the joints without damage to the material. It shall not flow from the joints or be picked-up and tracked by vehicle tyres in summer temperatures.

A.2.2 The application temperature shall be at least 11 °C lower than the safe heating temperature. The safe heating temperature is defined as the highest temperature to which the material can be heated and still meet all requirements of the Specification. No sample of the material shall be tested until the manufacturer furnishes his recommended safe-heating and pouring temperatures.

A.2.3 Prolonged Heating: After 6 hours of continuous heating, with constant mixing in the laboratory at the manufacturer's recommended pour temperature, the joint sealer shall meet all requirements of the Specification.

A.2.4 Penetration: The penetration at 25 °C, 150 g, 5 sec, shall not be less than 50 or more than 90 mm.

A.2.5 Flow: The flow at 60 °C and at a 75-degree angle shall not exceed 1 cm in 5 hours.

A.2.6 Ductility: Ductility at 25 °C shall be not less than 35 cm.
A.2.7 Bond: The hot type joint sealing compound material when tested at minus 17.8 °C to 100 percent extension (1.27 cm extended to 2.54 cm) shall, after 5 cycles, show no surface checking, cracking, separation or other opening in the material or between the material and the block. At least 2 test specimens in a set of 3 specimens representing a given sample shall meet this requirement.

A.2.8 Resilience: Recovery shall be not less than 25 percent.

A.2.9 Compression recovery: Compression recovery of bond specimens shall be not less than 1 cm within 15 min.

A.2.10 Impact: No failure in cohesion or adhesion shall occur.

A.3 Methods of Sampling and Testing

A.3.1 Sampling: Samples for testing shall consist of not less than a 4.5 kilogram sample from each batch of the joint sealer. A batch shall be considered as all finished material manufactured simultaneously or continuously as a unit between the time of compounding and the time of packaging or placing in shipping containers. Each package or container shall be marked properly to indicate clearly the batch of which it forms a part. The material shall be sampled in accordance with the requirements of the "Standard Methods of Sampling Bituminous Materials" (ASTM Designation: D140) for solid materials in cakes.

A.3.2 Testing: Testing shall be in accordance with AASHTO T187 except that the tolerances on dimensions of test specimens, Article 6.3, shall be ± 0.13 cm and the temperature tolerances, Article 6.4 shall be ± 2.2 °C.

B. Cold Type Joint Sealing Compounds

B.1 Composition

Cold type material shall be homogeneous and of such consistency that it can be applied by high-pressure pumps through suitable nozzles to completely fill the joints. The compound may be blended with a suitable solvent or solvents by the manufacturer to provide better workability during installation in the joints. The solvents shall be sufficiently volatile that they will evaporate within a short time after installation leaving a material that is adhesive and resilient.

B.2 Physical Requirements

B.2.1 Flow: The flow during a 5-hour period at 60 °C shall not exceed 0.5 cm.

B.2.2 Penetration: After evaporation of the solvent, the penetration at 25 °C, 150 gm, 5 sec, shall not exceed 220 mm.
B.2.3 **Bond:** When the compound is tested at minus 17.8 °C, the development at any time during the test procedure of a crack, separation or other opening which is at any point over 64 mm deep in the material or between the material and the concrete block, shall constitute failure of the test specimen. The failure of more than 1 test specimen in a group of 3 specimens, representing a given sample of joint sealing compound shall be cause for rejection of the sample.

B.3 **Methods of Sampling and Testing**

Cold-type joint compounds shall be tested in accordance with ASTM D1851, except that material for test specimens (Article 7(c)) shall be stirred manually rather than mechanically.

B.4 **Preformed Joint Seals**

Preformed Polychloroprene Elastomeric Joint Seals shall comply with the requirements of AASHTO M220 (ASTM D2628).

C. **Movement Joints in Water Retaining Structures**

Joint sealants for movement joints in water retaining structures shall be polysulphide based compounds to BS EN ISO 11600:2003 and approved by the Engineer.

D. **Exposed Joint Sealants for Movement Joints**

Exposed joint sealants for movement joints shall be polysulphide rubber based compounds unless otherwise specified and subject to approval by the Engineer.

E. **Backing Strips for Movement Joints**

Backing strips shall be of a type recommended by the joint sealant manufacturer and approved by the Engineer.

5.21.3 **PREFORMED EXPANSION JOINT FILLER**

A. **Description**

Preformed expansion joint filler shall be a non-extruding and resilient bituminous type and shall have relatively little extrusion and a moderate to high amount of recovery after release from compression.

B. **Requirements**

Non-extruding and resilient types of expansion joint filler shall conform to all the requirements of the Standard Specification for "Preformed Expansion Joint Fillers for Concrete Paving and Structural Construction (Non-extruding and Resilient Bituminous Types)", AASHTO Designation M213 (ASTM D1751).
C. Movement Joint Sheet Material Filler in Water Retaining Structures

Expansion joints in water retaining structures shall be bonded granular cork to ASTM D1752 or ASTM D1751 and as approved by the Engineer.

5.21.4 CERTIFICATE OF GUARANTEE

The Contractor shall furnish the Engineer with a Manufacturer's Certificate of Guarantee for each type of joint material delivered to the Site. The certificate shall note compliance to the appropriate specifications and shall state the results of the tests performed on the material, as required by the specifications. The Contractor shall, when so directed by the Engineer, have the joint material tested for conformance to the applicable specifications at an approved testing laboratory. All costs connected with Certificate of Guarantee and any subsequent quality testing shall be at the Contractor's expense.

5.21.5 CONSTRUCTION

A. Joints shall be straight, vertical, horizontal or as detailed on the drawings or approved by the Engineer. Joints shall be formed to accommodate any projecting reinforcement.

B. Movement Joints are either:
   • Formed expansion joints
   • Formed contraction joints
   • Induced contraction joints.

C. Formed movement joints shall be constructed between rigid stop ends and formwork at formed movement joints to permit separate construction of structurally separate parts of the work.

D. The Contractor shall submit proposals for the positions of construction joints, where they are not coincident with movement joints, for approval by the Engineer.

E. To prepare for construction joints the face shall be lightly roughened to expose coarse aggregate unless otherwise instructed by the Engineer. The face shall be wetted and covered with a 1:1 cement and sand grout immediately prior to placing fresh concrete. Roughening shall not take place in areas less than 25 mm from arrises to surfaces exposed to view in the finished work. Small mortar lips shall be removed from exposed arrises using a carborundum stone. The face shall be clean and damp before fresh concrete is placed against it.

F. Side and end forms of concrete floors shall be square edged to the steel top surface.
G. External waterbars shall be nailed to forms prior to concreting and butt jointed in accordance with the manufacturer's instructions.

H. Movement joints shall be sealed strictly in accordance with the manufacturer's recommendations. Joints shall be thoroughly clean and dry, free from oil and loose material. Joint faces shall be wire brushed or grit blasted and cleaned out with compressed air. The joint faces shall then be allowed to dry. Exposed faces shall be have their edges masked with tape before priming and the tape removed immediately after sealing. Sealant shall be applied to ensure a maximum adhesion to the sides of the joints and a neat, smooth and clean finish.

5.21.6 MEASUREMENT

A. No part of this Section is a Bid Item and no measurement shall be made.

B. The materials provided for this Section will not be paid for directly, but will be considered included in the payment for other items of work appearing in the Bill of Quantities.
SECTION 5.22: DRAINAGE OF STRUCTURES

5.22.1 SCOPE

The work covered in this Section consists of furnishing and installing gully and channel grates and frames on bridge decks, subways and underpasses for collecting surface water from structures. It shall also cover furnishing and installing hoppers, drain pipes and downpipes that are connected to gully and channel grates.

5.22.2 MATERIALS

A. Gully and Channel Grates and Frames

Frames and grating shall comply with AASHTO M105 (ASTM A48) or BS EN 124:1994 Part 1 for cast iron.

B. Steel Pipes

Cast iron pipes shall conform to the requirements of BS EN 545:2006. Steel pipes shall conform to the requirements of BS EN 10224:2002 and BS EN 10311:2005.

C. PVC and uPVC Pipes

Pipes of synthetic materials for general drainage use shall be polythene, polypropylene or polyvinylchloride as detailed on the Drawings or approved by the Engineer. Unplasticised polyvinylchloride pipes shall conform to the requirements of Class 2 and Class 3 in ASTM D 3033.

5.22.3 CONSTRUCTION

A. Drainage pipes and gullies shall be laid to the lines and levels and bedded, laid, jointed and protected, all as shown on the Drawings or as established by the Engineer.

B. When drainage pipes are cast into concrete structures, the Contractor shall take adequate precautions to prevent any displacement of the pipes during the concreting operation.

C. Drainage pipes shall be tested for watertightness and the test procedure shall be agreed with the Engineer. Where drainage pipes are located within the cellular parts of a bridge deck where access after completion of the deck is limited, then the installation and testing of the pipes shall be completed and accepted by the Engineer before the deck construction is allowed to proceed to the stage where free access to the pipes is not possible.
5.22.4  MEASUREMENT

A. Gully box, grates and frames of different types shall be measured by the number installed, completed, and accepted. Hoppers connecting the gully frames to drainage pipes shall not be measured separately but their costs shall be considered included in the rates for gully grates and frames.

B. Different types of channel grates and frames shall be measured by the linear metre installed, completed, and accepted. Hoppers connecting channel frames to drainage pipes shall not be measured separately but their costs shall be considered included in the rates for channel grates and frames.

C. Different types of drainage pipes shall be measured by the linear metre of each diameter and each type of pipe installed, completed and accepted. No separate measurement will be made for pipes cast into concrete or for pipes connecting gully and channel frames to drainage pipes or for pipe supports and joints or for discharge hoppers from drainage pipes to down-stand pipes, but their costs shall be considered included in the rates for drainage pipes.

D. No separate measurement will be made for testing of gully grates and frames, gully hoppers, drainage pipes and their support system but their costs shall be considered included in the rates for the items tested.

E. The amount of completed and accepted work measured as provided above shall be paid at the unit price bid as specified in the Bill of Quantities, the prices of which shall be full compensation for furnishing all materials, labour, equipment, tools, supplies and all other items necessary for the completion of the work.

PAY ITEMS                                                   UNIT OF MEASUREMENT

(5.22.1)  Gully, Grates and Frames (state type)           Number (No)
(5.22.2)  Channel Grates and Frames (state type)         Linear Metre (m)
(5.22.3)  Iron Pipes (state type and diameter)           Linear Metre (m)
(5.22.4)  Steel pipes (state type and diameter)          Linear Metre (m)
(5.22.5)  uPVC pipes (state type and diameter)           Linear Metre (m)
(5.22.6)  PVC pipes (state type and diameter)            Linear Metre (m)
SECTION 5.23: CONCRETE PILING

5.23.1 SCOPE

A. The work covered in this Section consists of furnishing, driving, placing or installing, load testing, and completing concrete and steel piles as and where shown on the Drawings or as directed by the Engineer.

B. Materials manufacture, driving, concreting, testing of concrete and steel piles, and steel sleeves shall be in accordance with the relevant requirements of BS 8004:1986 ASTM D1143; ASTM D3689; ASTM D3966; and "Piling Model Procedures and Specifications" (Institution of Civil Engineers) and as specified herein.

5.23.2 PILE MATERIALS AND MANUFACTURE

A. Cast in Situ Concrete Piles

A.1 Unless otherwise shown on the Drawings, concrete shall be Class 270/20 and shall conform to the requirements of Section 5.01: Concrete Mixes and Testing.

A.2 Reinforcement shall conform to the requirements of Section 5.03: Steel Reinforcement.

A.3 All shells and casings (and also the driving points of mandrel driven shells) shall be of types approved by the Engineer, having sufficient strength and rigidity to permit driving and to prevent distortion caused by soil pressure or the driving of adjacent piles. Shells shall be watertight and straight, tapered, step-tapered, or a combination of each with cylindrical sections.

A.4 Stepped or tapered shell sections shall have a minimum outside tip diameter of 200 mm and a minimum outside butt diameter as shown on the Drawings. Straight shells shall have a minimum outside diameter as shown on the Drawings. For pile shells with a fluted section, the diameter shall be measured from crest to crest of the flutes. All joints in the shell shall be electrically welded. The lower end of each section shall be provided with a steel driving point having a wall thickness of not less than 10 mm.

A.5 The Contractor shall ensure the stability of pile excavations by the use of temporary casings or an alternative method approved by the Engineer. Temporary casings shall be free from significant distortion and of uniform cross-section throughout their length. During concreting temporary casings shall to be free from internal projections and encrusted concrete.

A.6 Steel sleeves shall be ASTM A 283M, Grade C; or ASTM A 36M carbon-steel plate with vertical joints full-penetration welded according to AWS D1.1.

A.7 The thickness of the steel sleeve shall be not less than 20mm. The outer surface of the sleeve shall be blast cleaned and covered with an epoxy coating of
minimum thickness 0.4mm which consists of special coal-tar pitches modified with epoxy resins, and cured with isocyanate adducts.

B. Drilling Fluid

B.1 Bentonite: Where bentonite is to be used in the boring process the material shall conform to specification DFCP4 of the Oil Companies Association and the supplier shall submit a test certificate, representative of the material delivered, to show its apparent viscosity and gel strength ranges.

B.2 Bentonite properties: Bentonite suspension as supplied to the pile shaft shall conform to the following properties:

<table>
<thead>
<tr>
<th>Property</th>
<th>Range of results at 20°C</th>
<th>Test Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>Less than 1.1g/ml</td>
<td>Mud density balance</td>
</tr>
<tr>
<td>Viscosity</td>
<td>30 - 90s</td>
<td>Marsh cone method</td>
</tr>
<tr>
<td>Shear strength</td>
<td>1.4 – 10 N/m²</td>
<td>Shearometer</td>
</tr>
<tr>
<td>pH</td>
<td>9.5 - 12</td>
<td>pH indicator paper strips or electric pH meter.</td>
</tr>
</tbody>
</table>

5.23.3 CONSTRUCTION

A. General

A.1 Proposed Piling Methods

The Contractor shall submit to the Engineer for approval all relevant details of the method of piling and the plant he proposes to use. The method statement should include but not be limited to the following:

- Method of locating piles
- Boring method including procedures for checking verticality of shaft and cleaning pile base
- Method of installation of reinforcement cages
- Method of concreting in dry and wet conditions.
- Method of installation and coating of the steel sleeves.

A.2 Piling Programme

The Contractor shall inform the Engineer each day of the piling programme for the following day and shall give adequate notice of his intention to work outside normal hours.

A.3 Pile Boring Sequence
The Contractor shall submit his proposed sequence and timing for boring or driving piles having regard to the avoidance of damage to adjacent piles.

A.4 Daily Records

The Contractor shall submit daily records to the Engineer as follows:

- Pile reference number
- Diameter, working level and level of pile toe
- Date and time of boring or driving
- Date of concreting
- Depth from working level to pile head level
- Length of temporary casing
- Volume of concrete supplied to pile
- Records of any delay to boring, driving or concreting

A.5 Damage to Adjacent Structures and Services

The Contractor shall submit proposals for the avoidance of any damage due to piling to mains, services or adjacent structures and shall prepare contingency plans in case of such damage. Repairs to any damage so caused shall be carried out at the Contractor's expense.

A.6 Handling Piles

The method and sequence of lifting, handling, transporting and storing piles shall ensure that the piles are not cracked, chipped or otherwise damaged. Only the designed lifting and support points on the piles shall be used. During transportation and storage, piles shall be stored on adequate supports located under the lifting points of the piles.

A.7 Stresses in Concrete Piles

Concrete shall not be subjected to loading, including its own weight, which will induce a compressive stress exceeding one third of its strength at the time of loading or one third of the specified 28-day strength, whichever is the lower. The assessment of the strength of the concrete and of the stresses produced by the loads shall be subject to verification and approval by the Engineer.

A.8 Stacking Piles

All precast concrete piles within a stack shall be in groups of the same length. Packing of uniform thickness shall be provided between piles at the lifting points. Steel piles within a stack shall be in groups of the same length and on suitable supports. Operations such as handling, transporting and pitching of piles shall be carried carefully to avoid damage to piles and their coatings.

A.9 Damage to Piles
Piles determined by the Engineer to have been damaged in handling or driving shall be replaced by the Contractor at his own expense.

A.10 Bentonite Slurry

Where bentonite slurry is to be used during boring of piles a detailed method statement shall first be submitted to the Engineer for approval. Bentonite shall be thoroughly mixed and allowed to pre-hydrate for 24 hours before use and its properties shall ensure adequate support of the sides of the bore. Immediately prior to concreting, slurry shall be sampled from the level of the pile toe. The density of the slurry from such a test shall not exceed 1.2 gm/ml and the viscosity shall not exceed 75 Marsh seconds.

B. Jetting and Drilling

When necessary to obtain the specified penetration, the Contractor shall furnish and operate approved jetting equipment or suitable drilling equipment and drill holes no larger than the diameter of the pile, and drive the pile therein. Piles jetted or set in drilled holes shall be driven to the specified bearing capacity after completion of jetting or drilling.

C. Boring

C.1 Piles shall not be bored so close to previously concreted piles that concrete in the concreted piles is liable to damage.

C.2 Temporary casings or an alternative method approved by the Engineer shall be used to maintain the stability of the pile bore during excavation. Casings shall be free from distortion, clean, free from projections and shall be of continuous section throughout their length.

C.3 Where bentonite slurry is used in the excavation process to support pile bores, the slurry shall be maintained at an adequate level to ensure stability. A short length of top casing shall be used to ensure cleanliness during concreting and the stability of subsoil near ground level. The Contractor shall take suitable measures to prevent spillage of bentonite slurry on or in the vicinity of the Site. Used slurry shall be disposed of using a method approved by the Engineer.

C.4 Pumping from boreholes shall only be permitted where there is no risk of removal of fines from the subsoil.

C.5 When subsoil water which cannot be sealed off is encountered, the water in the bore shall be maintained above the standing level of subsoil water to prevent contamination. In such circumstances pile concrete shall be placed by tremie tube.

C.6 Piles shall be bored and concreted without delay. No significant time interval between operations shall occur to the detriment of the pile integrity.

C.7 On completion of boring, any loose soil shall be removed from the base of the pile and the Contractor shall provide such facilities as the Engineer may require for
inspection of the pile base. Any method of descent and equipment used shall conform to BS 8008:1996.

C.8 Joints in longitudinal steel reinforcing bars shall be permitted unless otherwise specified in the Drawings. The Contractor shall demonstrate to the Engineer that the full strength of the reinforcing bars shall be effective across the joint and that no displacement of the bars shall occur during concreting.

D. Permanent Protective Steel Casings

D.1 Steel casings shall be of minimum wall thickness specified on the Drawings.

D.2 Sleeve sections shall be connected by continuous penetration welds to form a watertight, continuous casing.

D.3 Casings that have been damaged during installation or casings where the coating has been damaged shall either be removed and replaced or repaired to the satisfaction of the Engineer.

D.4 Annular voids between the casing and shaft wall shall be filled with bentonite mix.

D.5 Preparation of surfaces and application of coatings shall be carried out by specialist labour approved by the Engineer.

D.6 Work on surface preparation and coating shall be undertaken inside a substantially built waterproof structure unless such work is the lengthening of a partly driven pile.

D.7 Surfaces to be coated shall be clean and dry after preparation.

D.8 Where necessary, degreasing shall be carried out using solvents compatible with coating and approved by the Engineer.

D.9 All surfaces to be coated shall be grit blasted with an approved abrasive to Sa 2.5 of BS 7079-A1:1989 (BS EN ISO 8501-1-2001). The grit shall not be manufactured from copper slag. Blast cleaning shall be carried out after fabrication unless otherwise approved by the Engineer. Unless an instantaneous recovery blasting machine is used, steel surfaces shall be blast cleaned with clean dry air or vacuum cleaned to remove residues and dust or other method approved by the Engineer.

E. Concreting for Cast in Situ Piles

E.1 Prior to placing concrete in a pile casing, the Contractor shall check that any permanent casing is undamaged and that the casing is free from water or other foreign matter. If water or foreign matter is present the Contractor shall propose and undertake the necessary action for removal when approved by the Engineer.
E.2 The method of placing and the workability of the concrete shall ensure that a continuous monolithic concrete shaft of the full cross section is formed. Concrete shall be placed without interruption. No spoil, liquid or foreign matter shall be allowed to contaminate the concrete. The workability of the approved mix shall be maintained in the pile concrete as it is placed. When placed in dry borings, measures shall be taken to avoid segregation and bleeding and to ensure that the concrete at the bottom of the pile is not deficient in grout.

E.3 Concrete placed under water or under slurry shall be placed only by tremie tube. Before concreting begins, all Site or other material shall be removed from the base of the bore. The tremie tube shall be clean and watertight throughout and of not less than 200 mm internal diameter. The end of the tremie pipe shall be kept immersed in the concrete to a minimum depth of 1 metre at all times. The tube shall not have external projections which may snag the reinforcement cage, damage or lift it.

E.4 Temporary casings shall be extracted while the concrete within remains workable. During extraction, sufficient concrete shall be maintained within the casing to ensure that the external pressures from groundwater and soil do not cause the pile to neck.

E.5 After each pile has been cast, any empty remaining bores shall be protected by temporary backfilling.

E.6 Immediately prior to concreting, slurry shall be sampled from the base of the boring using an appropriate sampling device. If the specific gravity of the slurry exceeds 1.2 or the marsh cone viscosity exceeds 75 seconds, placing of concrete shall not proceed until bentonite has been replaced in accordance with the Specification.

E.7 The Contractor shall submit to the Engineer the proposed sequence and timing for boring piles having regard to avoidance of damage to adjacent piles.

F. Reinforced and Prestressed Concrete Driving Shells or Casings for Cast in Situ Piles

F.1 An appropriate driving head of proper size and design for the size and type of hammer to be used shall be provided to distribute the hammer blows and to prevent damage to the steel or concrete shell or casing while driving.

F.2 Details of the proposed reinforced or prestressed concrete shells and driving heads shall be submitted to the Engineer by the Contractor for approval.

F.3 The Contractor shall at all times have available a suitable means of inspection to check the interior of the pile shells for their entire driven length.

F.4 Any shell that shows bends, kinks or other deformation incurred during the process of driving shall be replaced if so directed by the Engineer at the Contractor's expense.
F.5 All driven shells shall be inspected by the Engineer before being filled with concrete. Any water or other foreign substance shall be removed.

F.6 Upon approval, shells shall be filled with concrete as specified and in the presence of the Engineer.

F.7 Concrete shall not be placed until all driving within a 6 metre radius of the pile has been completed, unless otherwise approved by the Engineer.

G. Tolerances

G.1 Unless otherwise shown on the Drawings, the maximum horizontal tolerance for the heads of completed piles shall be 75 mm. Completed piles shall not be more than 10 mm/m out of vertical or out of the line of specified rake.

G.2 Piles which fail to meet the allowable horizontal and vertical (or rake) tolerances shall be, if directed by the Engineer, withdrawn and replaced or additional piles driven at approved locations, all at the Contractor's expense. Changing or attempting to change the line or position of any pile by forcible means shall not be permitted.

G.3 Cross-sectional dimensions of piles shall not be less than the nominal diameter by 5mm or more than 5mm.

H. Splicing and Cutting of Concrete Piles

H.1 When lengthening a concrete pile, the head shall be cut off square at sound concrete level, all loose particles removed by wire brushing and then washed with water.

H.2 Joints in reinforcement shall be designed and placed so that the full strength of the bar is effective across the joint.

H.3 Welded joints shall conform to BS EN 1011-2:2001 and the main longitudinal reinforcing bars in the head of the pile shall be exposed for at least 0.3 m below the weld.

H.4 For lap or splice joints, sufficient link bars shall be provided to resist eccentric forces.

H.5 If the pile is to be subjected to further driving, the Contractor’s proposals shall be subject to specific approval by the Engineer.

H.6 Repaired or lengthened piles shall not be driven until the added concrete has reached the specified characteristic strength of the pile concrete.

H.7 Procedures for repairing the head of a pile shall be as specified for pile lengthening. If the pile is to be subjected to further driving, the head shall be replaced.
H.8 All broken and waste concrete and reinforcement resulting from cutting heads of piles shall be disposed of as directed.

5.23.4 PILE TESTING

A. Pile testing shall be carried out as and when directed by the Engineer in conformity with the relevant requirements of BS 8004:1986, "Piling-Model Procedures and Specifications" (ICE); and with ASTM D 1143, ASTM D 3689 and ASTM D 3966 as appropriate to the type of pile and particular load test being carried out. Pile testing shall also conform to the following requirements.

B. Dynamic formulae shall not be used in place of pile tests to determine bearing values of piles.

C. Testing of the preliminary test piles shall be completed before commencement of piling in the Works.

D. The Contractor shall submit a full method statement and any specialist data required by the Engineer for approval before making any tests. Testing of preliminary piles shall also be completed before commencement of piling works. The location of the preliminary piles shall be approved by the Engineer.

E. Proposed test loading arrangements shall be submitted to the Engineer for approval before use. The test loads shall be applied by jacking against beams or the pile loading head and restrained by kentledge, ground anchors or reaction piles.

F. The maximum loads to be applied in maintained load and constant rate of penetration tests shall be as follows:
   - Preliminary pile compression test: 2.5 x working load.
   - Random working pile compression tests: 1.5 x working load.

G. The centre-to-centre spacing of vertical reaction piles from a test pile shall be not less than 3 x the diameter of the test pile or the reaction piles or 2 metres whichever is the greater. Where ground anchors are used to provide a test reaction for loading in compression, no part of the anchor transferring load to the ground shall be closer to the test pile than 3 x the diameter of the test pile.
H. Results shall be submitted to the Engineer at the conclusion of the tests in the form of tabulated field observations. For constant rate of penetration tests, load v settlement curves shall be submitted and for maintained load tests, the following shall be submitted:

- Time v settlement curves
- Time v load curves
- Load v settlement curves
- Settlement v log time for each stage
- Load v ds/d log time
- Load v settlement

I. Results of the preliminary tests shall be reviewed by the Engineer who will decide if the pile is acceptable, taking into account the acceptable total and differential settlements of the superstructure, the foundation geometry, the pile type and the soil conditions. Working piles that show materially different settlement characteristics compared to preliminary test piles shall not be accepted.

J. Loading and unloading for preliminary piles shall be as follows:

<table>
<thead>
<tr>
<th>Load: Percentage of Working Load</th>
<th>Minimum Time of Holding Load</th>
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<tbody>
<tr>
<td>25</td>
<td>1 hour</td>
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<td>50</td>
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<td>1 hour</td>
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K. Loading and unloading for working piles shall be as follows:

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<tr>
<th>Load: Percentage of Working Load</th>
<th>Minimum Time of Holding Load</th>
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<tbody>
<tr>
<td>25</td>
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L. In the event of the pile continuing to settle under constant load before the maximum test load has been reached, readings shall be taken at 15 minute intervals for a period of one hour while the load is being maintained. The pile shall then be unloaded in approximately 4 to 6 equal decrements at 15 minute intervals and allowed to recover for 3 hours. One set of settlement readings shall be taken after each decrement of load and a further set of readings at the end of the recovery period.

M. Following each application of increment of load, the load shall be held for not less than the period specified or until the rate of settlement is less than 0.25mm/hour and slowing. The rate of settlement shall be calculated from the slope of the curve obtained by plotting values of settlement versus time and drawing a smooth curve through the points. For the period when the load is constant, time and settlement shall be recorded immediately on reaching the load and at 15 minute intervals for 1 hour, 30 minute intervals between 1 hour and 4 hours and at hourly intervals between 4 hours and 24 hours after the application of the load increment.
N. Cast in situ piles shall be integrity tested by the steady state vibration or other method approved by the Engineer. The method shall be based on the measurement of the axial pile shaft point mobility at the pile head and shall be carried out by an experienced specialist test organization approved by the Engineer. A detailed method statement of the method intended together with interpretation procedures shall be submitted for approval by the Engineer prior to commencement of testing.

5.23.5 MEASUREMENT

A. Concrete Piling shall be measured by the linear metre of preliminary test piles and working piles furnished, constructed, installed or driven in either soil or rock, tested, completed, and accepted including all excavation, concrete, steel, protected steel sleeves and all other items necessary for the completion of the work. The measured length shall be from the tip to the point where the pile is cut away to provide for connection with the cap or footing.

B. Pile Tests shall be measured by the number of pile tests of each type carried out and completed and for which all specified information and data have been submitted and accepted.

C. Falsework piling, defective or damaged piling, pre-boring, jetting or other methods of facilitating driving, splicing, checks of straightness and tolerances, outer surface coating of sleeves and other ancillary piling work shall not be measured for direct payment, but shall be considered as included in the costs of the Contract prices for the other Pay Items.

<table>
<thead>
<tr>
<th>PAY ITEMS</th>
<th>UNIT OF MEASUREMENT</th>
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</thead>
<tbody>
<tr>
<td>(5.23.1) Concrete Piling (each type and size)</td>
<td>Linear Metre (m)</td>
</tr>
<tr>
<td>(5.23.2) Preliminary Pile Load Tests</td>
<td>Number (No)</td>
</tr>
<tr>
<td>(5.23.3) Working Pile Load Tests</td>
<td>Number (No)</td>
</tr>
<tr>
<td>(5.23.4) Integrity Tests</td>
<td>Number (No)</td>
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</table>
SECTION 5.24  INSPECTION, MAINTENANCE AND REPAIR OF STRUCTURES

5.24.1  SCOPE

A. The work covered in this Section consists of the structural investigation of existing bridges and other structures, the subsequent report and proposals for restoration.

5.24.2  INVESTIGATION

A. The Contractor shall investigate and report on the actual load capacity of the structure, ascertainment of the likely cause of structural distress and the listing of recommendations for its strengthening to serve the serviceability and live loads.

B. The investigation shall be completed by performing the following field and laboratory tests:

(a) Core tests
(b) Load tests

The design shall assess the present strength of the concrete (core tests) and the elastic response to the structure and its stiffness (load tests).

C. The design for the rehabilitation of the existing structure shall depend on the findings of the report and the Contractor's recommendation will be reviewed and approved by the Engineer. Payment for any additional strengthening work will be in accordance with the Contract conditions.

5.24.3  LOAD TESTING

The Contractor shall review and propose the method of load testing to the satisfaction of the Engineer, carry out the tests upon approval and present his findings.

5.24.4  CORE TESTING

A. The Contractor shall review and propose the method of core-testing identifying the location of the core samples and the method of laboratory testing to the satisfaction of the Engineer, carry out the test upon approval and present his findings.

B. Complementary non-destructive testing using ultrasonic equipment shall be included in the Contractor’s proposals.
5.24.5 MEASUREMENT

The provision of this section shall include the setting up, proposing, testing in any independent laboratory and preparation and presentation of the report.

<table>
<thead>
<tr>
<th>PAY ITEMS</th>
<th>UNIT OF MEASUREMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Load Tests</td>
<td>Lump Sum (LS)</td>
</tr>
<tr>
<td>(2) Core Tests</td>
<td>Lump Sum (LS)</td>
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