SERIES 1700
STRUCTURAL CONCRETE

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STRUCTURAL CONCRETE

1701 (05/04) Concrete - General

(05/04) Specification of Concrete

1 (05/04) Concrete shall conform to the requirements of BS 8500-2. Unless otherwise described in Appendix 17/4, concrete shall be specified as designed concrete. Details of the structural concrete in the Permanent Works are given in Appendix 17/1.

Design Concrete

2 (05/04) The specification for designed concrete shall contain:

(a) the basic requirements given in 4.3.2 of BS 8500-1;

(b) the additional requirements given in 4.3.3 of BS 8500-1 where required.

1702 (05/04) Concrete - Constituent Materials

Cement

1 (05/04) Cement types as defined in BS 8500 (see Table A.17 of BS 8500-1 or Table 1 of BS 8500-2) shall comprise one of the following, unless otherwise described in Appendix 17/4:

CEM I, CEM II/A-S, CEM II/B-S, CEM II/A-V[1], CEM II/B-V[1], CEM III/A, CEM IV/B[1] and SRPC.

Combinations as defined in BS 8500 shall comprise one of the following:

CIIA-S, CIIB-S, CIIA-V[1], CIIB-V[1], CIIIA and CIVB-V[1].

[1] The pfa used shall have a maximum colour index of 7 (Colour comparator disc reference no. 296570) when tested using the Lovibond Colour Comparator system as referred to in Annex A.7 of BS 3892 : Part 1.

(05/04) Aggregates

2 (05/04) Unless otherwise specified in Appendix 17/4, aggregates shall conform to the British Standards listed in 4.3 of BS 8500-2 except that recycled concrete aggregate (RCA) and recycled aggregate (RA) shall not be used.

The flakiness index of the coarse aggregate when determined by the method described in BS EN 933-3 shall not exceed FI_{35} except when natural, uncrushed aggregates are used for concrete of strength classes lower than C32/40, when the flakiness index shall not exceed FI_{50}. No limit is relevant to strength class C12/15 concrete or below.

When required, the resistance to fragmentation of the coarse aggregate, determined in terms of the Los Angeles coefficient as specified in BS EN 1097-2 and declared in accordance with the relevant category specified in Table 12 of BS EN 12620, shall meet the requirements for LA_{40}.

Note: Aggregates with LA coefficient values above 40 may also perform satisfactorily in normal concrete but their strength performance shall be established in concrete trials before use.

Chloride levels of the aggregates shall be determined daily, in accordance with the Volhard reference method in BS EN 1744-1, or less frequently when the long term variability has been established.

Admixtures and Pigments

3 (05/04) Admixtures shall conform to BS EN 934-2, unless otherwise described in Appendix 17/4. Where a specified coloured concrete requires a pigment, the pigment shall conform to BS EN 12878.

In all cases the Contractor shall record the following information:

(a) the detrimental effects caused by adding a greater or lesser quantity of admixture or pigment;

(b) the chemical name(s) of the main active ingredient(s);

(c) whether or not the admixture leads to the entrainment of air.

1703 (05/04) Concrete - Exposure Classes

(05/04) Selection of Exposure Classes

1 (05/04) Guidance is provided in Clause NG 1703.

1704 (05/04) Concrete - General Requirements

(05/04) Compressive Strength Class of Concrete

1 (05/04) Guidance is provided in Clause NG 1704.

(05/04) Minimum Cement Content and Maximum Water/Cement Ratio

2 (05/04) The cement content shall be not less than, and the water/cement ratio shall be not greater than, described in Appendix 17/1. See sub-Clauses NG 1704.2 to NG 1704.11 for guidance on selection of these parameters.

TABLE 17/1: (05/04) **Chloride content classes**

Type or use of concrete	Chloride content class	Maximum total chloride content expressed as % of chloride ion by mass of cement (inclusive of ggbs or pfa when these are used as cement)
Prestressed concrete, heat-cured concrete containing embedded metal	Cl 0,10	0.10%
Concrete containing embedded metal and made with cement conforming to BS 4027	Cl 0,20	0.20%
Concrete containing embedded metal and made with other permitted cements	Cl 0,30	0.30%

(05/04) Control of Alkali-Silica Reaction

5 (05/04) The concrete producer shall take action to minimize damaging alkali-silica reaction by applying one of the sets of conditions given in 5.2 of BS 8500-2.

High alkali Portland cement, with an acid-soluble alkali content greater than 0.75% sodium oxide equivalent, shall not be used, except where it is CEM I and used in combination with the appropriate quantity of ggbs or pfa as prescribed in BS 8500.

Extremely reactive aggregates, comprising those aggregates containing detectable quantities of opal, glass and calcined flint, shall not be used alone or in combination with other aggregates. The definition of rock types shall be as in BS EN 932-3.

(05/04) Buried Concrete Exposed to Sulfates

6 (05/04) Guidance is provided in sub-Clause NG 1704.11.

(05/04) Maximum Cement Content

3 (05/04) The cement content shall not exceed 550 kg/m3 unless otherwise described in Appendix 17/1.

Maximum Chloride Content

4 The chloride content class shall conform to the following requirements:

1705 (05/04) Concrete - Requirements for Designed Concrete

(05/04) Conformity Criteria

1 (05/04) The conformity criteria for a concrete shall be in accordance with BS EN 206-1.

(05/04) Suitability of Proposed Constituent Material Proportions

2 (05/04) The Contractor shall record, prior to the supply of any designed concrete, the following information:

(i) the nature and source of each material;

(ii) either:

(a) (05/04) appropriate existing data as evidence of satisfactory previous performance for target mean strength, current margin, consistence and water/cement ratio; or

(b) (05/04) full details of initial tests carried out in accordance with Annex A of BS EN 206-1;

(iii) (05/02) the quantities of each material per cubic metre of fully compacted concrete.

Any change in the source of material or in constituent material (except changes in cement content of not more than 20 kg/m^3 and pro-rata changes in aggregate contents) shall be subject to a re-assessment of the concrete in accordance with this sub-Clause.

1706 Concrete - Production

(05/04) **Production Control**

1 (05/04) All concrete shall be subject to production control under the responsibility of the producer, as specified in clause 9 of BS EN 206-1 and clause 11 of BS 8500-2.

Consistence At Delivery

2 (05/04) In general water or admixtures shall not be added to delivered concrete. In special cases, water or admixtures may be added where this is the responsibility of the producer and used to bring the consistence to the specified value provided that the limiting values, permitted by the specification, are not exceeded and the addition of admixture is included in the design of the concrete. The quantity of any additional water or admixture added to the truck mixer shall be recorded on the delivery ticket in all cases (see sub-Clause NG 1706.2).

1707 (05/04) Concrete - Conformity and Identity Testing

General

1 (05/04) Sampling and testing of fresh and of hardened concrete shall comply with BS EN 206-1 unless otherwise described in Appendix 17/4.

(05/04) **Identity Testing**

2 (05/04) Where identity testing for compressive strength is required, as described in Appendix 17/4, it shall be in accordance with the requirements given in Annex B of BS EN 206-1. Where identity testing for slump, flow and air content on individual batches of concrete, is required it shall be as described in Appendix 17/4. Guidance on the need for and rates of identity testing is given in Clause NG 1707.

1708 Concrete - Surface Finish

Trial Panels

1 (05/04) When required in Appendix 17/3 and before commencing concreting the Contractor shall prepare a trial panel of a suitable size that will demonstrate that the required surface finish can be achieved by the methods proposed.

The panel shall contain representative reinforcement and shall be filled with the proposed concrete compacted by the method to be used in the work. As soon as practicable after compaction, the forms shall be removed to check that the required surface finish and compaction has been achieved.

Reference panels have also been produced showing typical Class F2 and F4 Surface finishes made with local materials in each region of the UK and they can be viewed at various sites throughout the UK as described in sub-Clause NG 1708.4(ii).

Control of Colour

2 When stated in Appendix 17/1 each constituent material shall be obtained from a single consistent source. The aggregates shall be free of any impurities that may cause staining. The mix proportions and the grading, particularly of the sand (ie fine aggregate), shall be maintained constant. The same type of plywood or timber shall be used in formwork throughout similar exposed areas.

Release Agents

3 (05/01) Release agents for the formwork shall enable the formwork to be removed without damage to the concrete surface. There shall be no adverse residual effect from the release agent on the concrete surface. Where a concrete surface is to be permanently exposed, only one agent shall be used throughout the entire area. Release agents shall be applied evenly and shall not be permitted to come into contact with reinforcement, prestressing tendons and anchorages. Any such contact areas shall be washed free of contamination.

Where the concrete is to receive an applied finish, or surface impregnation, release agents shall be compatible with that particular process.

Surface Finishes for Concrete

4 (i) (05/01) Formed Surfaces - Classes of Finish

Formwork as described in sub-Clause 1710.2 shall be capable of producing the following finishes where required in the Works:

Class F1. No extra requirement.

Class F2. The irregularities in the finish shall be no greater than those obtained from the use of wrought thicknessed square edged boards arranged in a uniform pattern. The finish is intended to be left as struck but imperfections such as fins and surface discolouration shall be made good.

Class F3. The resulting finish shall be smooth and of uniform texture and appearance. The formwork lining shall leave no stain on the concrete and shall be so joined and fixed to its backing that it imparts no blemishes. It shall be of the same type and obtained from only one source throughout any one structure. The Contractor shall make good any imperfections in the finish. Internal ties and embedded metal parts shall not be used.

Class F4. The requirements for Class F4 are as for Class F3 except that internal ties and embedded metal parts shall be permitted. The ties shall be positioned only in rebates or in other positions as described in Appendix 17/3.

Class F5. The resulting finish shall be smooth and of uniform texture. Any blemishes and imperfections, such as discolouration and fins, shall be made good. Provision for the embedment of metal parts in the Permanent Works on a regular spacing, shall be allowed.

Other classes. The finishes shall comply with the specific requirements described in Appendix 17/3.

Permanently exposed concrete surfaces to all Classes of finish other than F1 shall be protected from rust marks and stains of all kinds.

Unless otherwise described in Appendix 17/3, all formwork joints for all classes of finish other than F1 shall form a regular pattern with horizontal and vertical lines continuous throughout each structure and all construction joints shall coincide with these horizontal or vertical lines.

(ii) Unformed Surfaces - Classes of Finish

Class U1 finish. The concrete shall be levelled and screeded to produce a uniform surface to the profile shown on the Drawings. No further work shall be applied to the surface unless it is used as a first stage for another class of finish.

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

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

Class U4 finish. The concrete shall be levelled and screeded to produce a uniform surface. When the concrete has sufficiently hardened and the bleed water evaporated the surface shall be trowelled to produce a hard dense surface free from screed marks and exposed aggregate. Finally the surface shall be lightly textured with a wooden float or equivalent.

Alternatively the concrete shall be levelled, screeded and floated to produce a uniform surface and immediately before the waterproofing operation this surface shall receive surface preparation by water jetting or grit blasting to provide a lightly textured finish.

The finished surface shall not deviate from the required profile by more than 10 mm over a 3 m gauge length or have any abrupt irregularities more than 3 mm.

Class U5 finish. The concrete shall be levelled and screeded to produce a uniform finish. When the concrete has sufficiently hardened to prevent laitance being worked to the surface it shall be floated to produce a surface free from screed marks and exposed aggregate. Finally the surface shall be textured to suit the requirements of the particular waterproofing and surfacing system. The accuracy of the finished surface shall be such that it does not deviate from the required profile by more than 5 mm over a 3 m gauge length or have any abrupt irregularities.

Other classes. The finishes shall comply with the specific requirements described in Appendix 17/3.

1709 (05/01) Concrete - Surface Impregnation

General

1 Impregnation shall be applied to those surfaces described in Appendix 17/2 in accordance with the manufacturer's instructions unless otherwise directed by Contract Documents or agreed by the Overseeing Organisation. The works shall in addition, be carried out in accordance with Health and Safety requirements, COSHH requirements and Waste Disposal Authority requirements.

Material

2 (i) The material for impregnation shall be monomeric alkyl (isobutyl)-trialkoxy-silane with a minimum active content of 92% delivered to the Site in sealed containers.

(ii) The refractive index of the material shall comply with the value stated in the manufacturer's product specification, within a limit of 0.003 units. The refractive index shall be checked as follows:

(a) Collect samples of the material from a newly opened container and from the spraying nozzle.

(b) Measure the refractive index of three samples from both the container and spray nozzle using a portable refractometer.

(c) Measure the temperature of the samples (portable refractometers have temperature measuring capability).

(d) Correct the refractive index measurements to the temperature stated in the manufacturer's product specification.

(e) If the temperature corrected measured value of the refractive index exceeds the manufacturer's specified value by more than 0.003 units then a laboratory check shall be undertaken to confirm compliance.

(iii) The Contractor shall obtain with each delivery a certificate that the material in that delivery complies with sub-Clause 2(i) of this Clause. No material shall be used in the works until the Certificate of Compliance has been accepted by the Overseeing Organisation.

(iv) The material shall be stored in a secure facility that has a dry frost-free environment protected from direct heat.

(v) The containers shall remain sealed until their contents are required for use. The contents of any opened container shall be used within 48 hours or else disposed of safely, in accordance with sub-Clause 7 of this Clause.

(vi) Materials offering a performance in respect of the protection of concrete and long term durability equivalent to that of monomeric alkyl (isobutyl)-trialkoxy-silane will be accepted. The assessment of the durability of an alternative surface applied hydrophobic pore lining impregnating material will be based on the provision of evidence that it has, in practice, provided an effective water repellent but vapour-permeable layer at the concrete surface for a period of not less than 15 years after application.

Spraying Equipment

3 (i) A power driven continuously circulating pumped system operating at a low nozzle pressure shall be used to apply the material in such a way as to avoid atomisation. Water shall be prevented from entering any part of the equipment.

(ii) A pressure gauge shall be installed between the trigger valve and spray lance to enable the pressure to be monitored.

(iii) A 'kill' switch shall be provided so that the pumping system may be stopped immediately should this be required.

Protective Measures

4 (i) Use and handling of the silane material shall be in strict accordance with the manufacturer's recommendations, and in full compliance with all current Health and Safety legislation. The Contractor shall ensure that only fully trained operatives undertake impregnation operations, and where necessary carry out trials to verify procedures.

(ii) Measures shall be taken to ensure that no impregnation material enters into any drainage system or watercourse. The Contractor shall obtain all necessary written permissions and licences from the appropriate authorities, prior to any silane operations above or adjacent to any watercourse.

(iii) Measures shall be taken to ensure that no impregnation material comes into contact with any humans, animals, vegetation or

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vehicular traffic by providing suitable and adequate protection and traffic management. The Contractor shall obtain approval from the Overseeing Organisation and all other authorities' licenses, agreements and permissions associated with traffic safety, management and protective measures in advance of the commencement of impregnation operations.

(iv) Elastomeric bearings, painted steel surfaces, exposed bituminous materials, and joint sealants adjacent to structural elements to be impregnated shall be masked off or covered before and during impregnation operations.

(v) In the case of spillage, action shall immediately be taken to limit the extent of the spillage and the Overseeing Organisation and other relevant authorities shall be informed at once.

(vi) After completion of impregnation operations, all contaminated protective sheeting and materials used for masking or covering, shall be disposed of in accordance with sub-clause 7 of this clause.

Surface Condition

5 (i) Areas to be treated shall be protected from adverse effects of the weather and shall be surface dry for a minimum of 24 hours before application commences. Artificial drying of surfaces shall not be permitted

(ii) Surfaces shall be free from loose or deleterious matter and residues of curing membranes, release agents graffiti and graffiti removal agents. The Contractor shall ensure that any harmful residual effects from the application of curing membranes are not present before impregnation commences. Existing structures shall be hand brushed with a stiff bristle brush to remove surface deposits. Where deleterious surface deposits cannot be removed using a stiff bristle brush they shall be removed by light grit blasting.

(iii) Water jetting or steam cleaning shall not in general be used as a means of surface preparation.

Application

6 (i) The Contractor shall submit a method statement to the Overseeing Organisation and shall obtain the Overseeing Organisation's written approval before commencing impregnation operations.

(ii) Impregnation of the face of a structural element shall be carried out in a single continuous operation for each application.

(iii) (05/04)Impregnation shall be carried out not less than 7 days after the concrete has been placed, or 3 days after concrete repairs have been completed on a structural element. Particular attention is drawn to compliance with sub-Clauses 5(i) & (ii) of this Clause.

(iv) The material shall be applied by continuous spray technique giving saturation flooding, working from the lowest level upwards. Two applications shall be made each at a coverage of 300 ml/m² with an interval between each of at least six hours.

(v) Impregnation shall not be carried out in the following conditions:

(a) when the shade temperature is below 5°C;

(b) when the temperature of the concrete surface is greater than 25°C;

(c) When the wind speed is in excess of 8 km/hr unless the working area is fully encapsulated.

(vi) Members shall be protected from rain and spray during application and for at least six hours after completion.

Disposal

7 Disposal of impregnation material, any contaminated materials and protective sheeting or masking, shall be in strict accordance with the requirements of the Waste Disposal Authority. Whilst on site, all such materials must be retained in a safe and secure facility. The Contractor shall obtain all necessary certificates of approval for the disposal of the materials.

Testing and Monitoring

8 (05/04) Where required in the Contract, the Contractor shall carry out impregnation on trial panels 2m x 2m or equivalent area, one on each of a vertical and horizontal surface. The Contractor shall then demonstrate on these panels, that the proposed method of working will meet the appropriate requirements of this Clause.

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1710 Concrete - Construction General

Construction Joints

1 The position of construction joints shall be as shown on the Drawings and at additional positions determined by the Contractor in accordance with the requirements of Appendix 17/4. When concrete is placed in vertical members, walls, columns and the like, the lifts of concrete shall finish level or, in sloping members, at right angles to the axis of the members, and the joint lines shall match features of the finished work, if possible, or be formed by grout checks. Kickers shall be constructed integrally with the lift of concrete below.

Concreting shall be carried out continuously up to construction joints.

Construction joints shall be prepared in either of the following ways:

(i) When the concrete is self-supporting but still sufficiently green, the formwork shall be removed, as necessary to expose the construction joint, subject to the requirements of sub-Clause 5 of this Clause. The concrete surface shall be sprayed with a fine spray of water or brushed with a stiff brush, just sufficiently to remove the outer mortar skin and expose the larger aggregate without disturbing it. Alternatively where this preparation proves impracticable the hardened surface skin and laitance shall be removed by grit blasting or a needle gun. Hardened surfaces shall not be hacked.

(ii) By the use of proprietary steel open-mesh permanent formwork.

Retarding agents shall not be used unless permitted in Appendix 17/4.

The joint surface shall be clean and damp but free of standing water immediately before any fresh concrete is placed against it.

Formwork

2 (i) (05/01) Design and construction. The formwork shall be sufficiently rigid and tight to prevent loss of grout or mortar from the concrete at all stages and for the appropriate method of placing and compacting.

The formwork shall be so arranged as to be readily dismantled and removed from the cast concrete without shock, disturbance or damage. Where necessary, the formwork shall be so arranged that the soffit form, properly supported on props only, can be retained in position for such period as may be required by maturing conditions as described in sub-Clause 1710.4(ii). If the component is to be prestressed whilst still resting on the soffit form, provision shall be made to allow for elastic deformation and any variation in weight distribution.

Where it is intended to re-use formwork it shall be thoroughly cleaned and made good.

Internal metal ties which require to be withdrawn through hardened concrete shall not be used where either face is permanently exposed. Where internal ties are left in, they shall be provided with a mortar cover of at least 50mm. The pocket shall be scabbled and dampened immediately prior to mortar filling.

(ii) Cleaning and treatment of forms. The faces of the forms in contact with the concrete shall be clean and treated with a suitable release agent, where applicable as described in sub-Clause 1708.3.

Immediately before concreting, all forms shall be thoroughly cleaned out. The source of any compressed air used for the clearing of foreign matter from formwork shall be free from oil and other contaminant.

(iii) Projecting reinforcement and fixing devices. Where holes are needed in forms to accommodate projecting reinforcement or fixing devices, care shall be taken to prevent loss of grout when concreting or damage when striking forms.

(iv) Permanent formwork shall comply with Appendix 17/4.

Transporting, Placing and Compacting

3 (05/04) Concrete shall be so transported and placed that contamination, segregation or loss of the constituent materials does not occur.

Concrete, when deposited, shall have a temperature of not less than 5°C and not more than 30°C. Fresh concrete shall not be placed against in situ concrete that has been in position for more than 30 minutes unless a construction joint is formed as described in sub-Clause 1 of this Clause.

Concrete shall not be pumped or discharged through aluminium alloy conduits.

No concrete shall be placed in flowing water. Underwater concrete shall be placed in position by tremies or by pipelines.

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Concreting operations shall not displace reinforcement, tendon ducts, tendon anchorages or formwork, or damage the faces of formwork.

Concrete shall be thoroughly compacted by vibration during the operation of placing, and thoroughly worked around the reinforcement, tendons or duct formers, around embedded fixtures and into corners of the formwork to form a solid mass free from voids. When vibrators are used to compact the concrete, vibration shall be applied continuously during the placing of each batch of concrete until the expulsion of air has practically ceased and in a manner that does not promote segregation of the ingredients.

It should be noted that self-compacting concrete (SCC) is not permitted under this Specification, however reference should be made to sub-Clause NG 1710.3.

Particular care shall be taken when concreting bridge decks of substantial thickness to avoid layering of concrete, and the whole thickness shall be placed in one pass. In deck slabs where void formers are used, adequate means to prevent flotation shall be employed and care taken to ensure adequate compaction of the concrete placed beneath the void formers.

A sufficient number of vibrators in serviceable condition shall be on site to ensure that spare equipment is always available in the event of breakdowns.

Vibration shall not be applied by way of the reinforcement. Where vibrators of the immersion type are used, contact with reinforcement and inserts shall be avoided as far as is practicable.

Concrete shall not be subjected to disturbance between 4 hours and 24 hours after compaction except that re-compaction of the upper layers of deep lifts to prevent or anneal settlement cracking may be carried out. Whenever vibration has to be applied externally, the design of formwork and disposition of vibrators shall ensure efficient compaction and the avoidance of surface blemishes.

There shall be no excess water on the top surface on completion of compaction.

Striking of Formwork

4 (i) (05/01) General. Formwork shall be removed in a manner not to damage the concrete, and at times to suit the requirements for its curing and to prevent restraint that may arise from elastic shortening, shrinkage or creep.

(ii) (05/04) Striking period. Where the concrete compressive strength is confirmed by tests on concrete cubes stored under conditions that simulate the field conditions, formwork supporting concrete in bending may be struck when the cube strength is 10 N/mm² or three times the stress to which it will be subjected, whichever is the greater.

For ordinary structural concrete made with Portland cement (CEM I) or sulfate-resisting Portland cement (SRPC) of strength class 42.5 or above, in the absence of control cubes the period before striking shall be in accordance with the minimum periods given in Table 17/2.

TABLE 17/2: (05/04) **Minimum Period Before Striking Formwork (CEM I or SRPC Concrete)**

	Minimum Period Before Striking		
	Surface temperature of concrete:		
	16°C	**7°C**	**t°C (any temperature between 0°C and 25°C)**
Vertical formwork to columns, walls and large beams	12 hours	18 hours	300 hours t + 10
Soffit formwork to slabs	4 days	6 days	100 days t + 10
Props to slabs	10 days	15 days	250 days t + 10
Soffit formwork to Beams	9 days	14 days	230 days t + 10
Props to beams	14 days	21 days	360 days t + 10

Where surface temperatures of concrete fall outside or are likely to fall outside the above temperature ranges agreement should be reached between the Contractor and Overseeing Organisation on appropriate striking times.

Curing of Concrete

5 (i) (05/04) Curing methods. Immediately after compaction and thereafter for the curing time, except where elevated temperature curing is used, concrete shall be protected against harmful effects of weather, including rain, rapid temperature changes, frost, and from drying out. The method of curing shall provide a suitable environment for the concrete to mature and prevent harmful loss of moisture.

The curing time shall be the number of days given in Table 17/3 unless the average surface temperature of the concrete during the required number of days falls below 10°C, in which case the period of curing shall be extended until the maturity of the concrete reaches the value given in the table.

The Contractor shall keep records of all curing liquids, compounds and membranes and their subsequent removal from the areas scheduled in Appendix 17/2. Where the Contractor proposes to use a curing liquid, compound or membrane on surfaces on which a waterproofing system is to be laid, it shall be completely removable.

Where the Contractor proposes the use of a curing liquid, compound or membrane on surfaces scheduled in Appendix 17/2, it shall be of a film type that fully degrades by exposure to ultra-violet light without leaving any residue that is detrimental to the surface impregnation of the concrete.

TABLE 17/3: (05/04) **Minimum Periods of Normal Curing for Different Types of Cement**

Conditions under which concrete is maturing	**Number of days (where the average surface temperature of the concrete exceeds 10°C during the whole period)**			**Equivalent maturity (degree hours) calculated as the age of the concrete in hours multiplied by the number of degrees Celsius by which the average surface temperature of the concrete exceeds -10°C**		
	Other*	SRPC	PC	Other*	SRPC	PC
1. Hot weather or drying winds	7	4	3	3500	2000	1500
2. Conditions not covered by 1	4	3	2	2000	1500	1000

NOTE. Other* includes all permitted cements except PC and SRPC.
(05/02) PC = Portland cement (CEM I).
SRPC = Sulfate-resisting Portland cement.

(ii) (05/02) Accelerated curing. Elevated-temperature curing as described below may be used only with Portland cement (CEM I) or sulfate-resisting Portland cement.

(a) The formwork may be generally heated to no more than 20°C prior to the placing of concrete.

(b) Once placing is complete the concrete shall be left for 4 hours without additional heating. The concrete temperature can then be raised at a maximum rate of 10°C per ½hour.

(c) The concrete temperature shall at no time exceed 70°C.

(d) The rate of subsequent cooling shall not exceed the rate of heating.

(e) Cubes shall be manufactured and cured under identical conditions to those to which the concrete is subjected.

The use of accelerated curing methods for concrete containing other types of cement or any admixture shall not be used.

Cold Weather Work

6 When concrete is placed at air temperatures below 2°C, the following requirements shall be met:

(i) The aggregates and water used in the mix shall be free from snow, ice and frost.

(ii) The surface temperature of the concrete at the time of placing shall be at least 5°C and shall not exceed 30°C.

(iii) The surface temperature of the concrete shall be maintained at not less than 5°C until the concrete reaches a strength of 5 N/mm² as determined by tests on cubes that were cured under identical conditions to the structural concrete.

(iv) Before placing concrete, the formwork, reinforcement, prestressing steel and any surface with which the fresh concrete will be in contact shall be free from snow, ice and frost.

(v) Cement shall not be allowed to come into contact with water at a temperature greater than 60°C.

Hot Weather Work

7 During hot weather the Contractor shall ensure that the constituent materials of the concrete are sufficiently cool to prevent the concrete from stiffening in the interval between its discharge from the mixer and compaction in its final position.

Cement shall not be allowed to come into contact with water at a temperature greater than 60°C.

Precast Concrete Construction

8 (i) (05/01) Manufacture off the Site. The Contractor shall give reasonable notice to the Overseeing Organisation in advance of the date of commencement of manufacture and casting of each type of member.

A copy of all 28-day cube test results relating to the work shall be made available.

For all prestressed members, the Contractor shall obtain, not more than 7 days after the transfer of stress, a certificate showing the force and extension in the tendons after they were anchored, the strength and age of test cubes cast as described in sub-Clause 1724.4(iv) and the minimum age in hours of the concrete at the time the stress was applied to the member.

For all prestressed pretensioned members the length, cross-section dimensions and straightness of precast concrete shall be measured at 28 ± 2 days after casting. Unless otherwise stated, and notwithstanding the requirements of (iv) below, the allowable dimensional variations shall not exceed the following:

Length	Variation
Up to 3 m	± 6 mm
3 to 4.5 m	± 9 mm
4.5 to 6 m	± 12 mm
Additional for every subsequent 6 m	± 6 mm
Cross section (each direction)	
Up to 500 mm	± 6 mm
500 to 750 mm	± 9 mm
Additional for every subsequent 250 mm	± 3 mm
Straightness or bow (deviation from intended line)	
Up to 3 m	± 6 mm
3 to 6 m	± 9 mm
6 to 12 m	± 12 mm
Additional for every subsequent 6 m	± 6 mm

The above allowable dimensional variations have not been taken into account in the bar schedules (Clause 1713 refers).

Where tests are to be carried out, no members to which the tests relate shall be dispatched to the Site until the tests have been satisfactorily completed.

All members shall be indelibly marked to show the member mark as shown on the Drawings, the production line on which they were manufactured, the date on which the concrete was cast and, if they are of symmetrical section, the face that 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.

Unless otherwise specified the vibrated top surface of precast concrete members which will subsequently receive in situ concrete shall be further prepared by one of the following methods as shown on the Drawings:

Class 1 surface preparation,

The surface finish shall be in accordance with sub-Clause 1 of this Clause.

Class 2 surface preparation,

The hardened surface shall be jetted with air or water to remove laitance and all loose material and no further roughening shall then be carried out (rough as cast).

(ii) Storage. When members are stored, they shall be firmly supported only at the points described in Appendix 17/4. The

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accumulation of trapped water and deleterious matter in the units shall be prevented. Care shall be taken to avoid rust staining and efflorescence.

When a stack is several units high, packings shall be vertically above each other to prevent additional bending stresses in any unit. Where disfigurement would be detrimental, packing pieces shall not discolour or otherwise permanently damage the units.

(iii) Handling and transport. Members shall be lifted or supported only at points described in Appendix 17/4 and shall be handled and placed without impact.

(iv) Assembly and erection. In a composite slab bridge where precast beams are laid side by side with minimal gaps to form a deck:

(a) the difference in soffit level between adjacent units before the in situ concrete is placed shall nowhere exceed 5 mm for units up to 5 m in length or 10 mm for longer units;

(b) the width of the deck soffit shall be within + 25 mm of that shown on the Drawings;

(c) in adjacent spans, the continuity of line of the outside beams shall be maintained;

(d) the width of the gap between individual beams shall not exceed twice the nominal gap shown on the Drawings;

(e) the alignment of transverse holes shall permit the reinforcement or prestressing tendons to be placed without distortion.

The in situ concrete in composite slab bridges shall be placed in such a sequence that the advancing edge of the freshly deposited concrete over the full width of the deck, between longitudinal construction joints, is approximately parallel to the deck supports. Precast beams shall be prevented from moving laterally during the placing of the in situ concrete.

The method of assembly and erection shall comply with any particular requirements in Appendix 17/4.

(v) Forming structural connections. The composition and water/cement ratio of the in situ concrete or mortar used in any connection and in the packing of joints shall be in accordance with the assembly instructions.

Levelling devices shall only be released or removed when the structural connection is complete and has achieved sufficient strength.

(vi) Protection. At all stages of construction, precast concrete units and other concrete associated therewith shall be properly protected to prevent damage to permanently exposed concrete surfaces, especially arrises and decorative features.

1711 (05/01) Concrete - Grouting and Duct Systems for Post-tensioned Tendons

Planning, Trials and Basic Requirements

1 (11/03) Site operations, including duct installation, stressing and grouting, shall be carried out by organisations certificated by CARES in accordance with the requirements of the CARES Scheme for the Supply and Installation of Post-tensioning Systems in Concrete Structures, or an equivalent scheme.

Grouts for protection of prestressing tendons shall be as required in Appendix 17/6 and defined in sub-Clause 1711.2.

The Contractor shall undertake full-scale trials of the grout mix and of the grouting operations as required in the Contract for duct installation, testing, concreting, grouting and any other associated requirements in accordance with the details described in Appendix 17/6. The trials are required to demonstrate that the grouting methods and procedures proposed by the Contractor shall ensure that grout fills the ducts and surrounds the prestressing steel.

The Contractor shall submit for acceptance of the Overseeing Organisation, a detailed method statement, at least 4 weeks prior to use in any trials or in the Works, covering proposed materials, ducts, anchorage and vent arrangements, personnel, equipment, grouting procedures and quality control.

Where full scale trials are required, these shall be commenced at least 56 days before the planned commencement of fixing ducts for prestressing for the permanent works unless specified otherwise in Appendix 17/6. The trials shall incorporate all relevant details of ducts, vents, duct supports, prestressing anchorages and couplers, prestressing strands, grout inlets and outlets. The tendons shall be sufficiently tensioned such that the strands within the duct take up a representative alignment. All systems, methods and

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materials are to be those proposed for the permanent works and shall have been submitted to the Overseeing Organisation as part of the detailed method statement required.

After three days the Contractor shall carefully cut or core the trial section to expose cross sections and longitudinal sections of the duct, anchorages and any other locations where required, or as further directed by the Overseeing Organisation, to demonstrate that the duct is satisfactorily grouted. A report shall be prepared by the Contractor giving full details of the trial, testing results and photographs of the exposed sections.

Grouting of the ducts shall be shown to leave no void which has either a dimension greater than 5% of the duct diameter measured in the radial direction of the duct or greater than 200 mm measured in the longitudinal direction of the duct (or appropriate dimension, in the case of oval ducts, anchorages etc) or which poses a risk to the protective system. The location of any voids with respect to grout vents and their adequate grouting and subsequent sealing, and the disposition of the steel tendons within the body of the grout shall be reported in writing by the Contractor to the Overseeing Organisation within 24 days.

Prestressing for the permanent works shall not be permitted without the prior written acceptance of the Overseeing Organisation to grouting procedures and formal acceptance of the results of the grouting trial.

The Contractor shall carry out a materials suitability assessment in accordance with sub-Clause 1711.2.

Grout Materials

2 (11/03) The properties of the grout, made with the materials, and using the plant and personnel proposed for use on site, shall be assessed for suitability for the intended purpose. This assessment shall be carried out sufficiently in advance of grouting operations to enable adjustments to be made in use of materials or plant or personnel.

Grouts shall comply with the requirements in sub-Clause 1711.8. The materials' assessment shall consist of the preparation of the grout, made with the materials, and using the plant and personnel proposed for use on site, and the testing of it in accordance with sub-Clause 1711.9. The preparation shall be carried out under representative conditions of temperature expected on site. If grouting operations are likely to cover different seasons, the assessment shall be carried out for the expected range of temperatures.

No departures from the sources of the materials and procedures approved as a result of satisfactory trials will be permitted without the written approval of the Overseeing Organisation.

Grouts shall consist only of Portland cement (CEM I) complying with BS EN 197-1 Class 42.5N, admixtures complying with sub-Clause 1711.10 and water complying with BS EN 1008. Where proprietary prebagged grout is used it shall be mixed in accordance with the manufacturer's instructions.

Grouts shall not contain a chloride ion content of more than 0.1% by mass of the cement.

Duct Systems

3 (11/03) The system of ducts, duct connectors, grouting connections, vents, vent connections, drains, transitions to anchorages and caps for anchors shall form a complete encapsulation for the tendons which is resistant to the ingress of air and water. Ducts shall be of proven corrosion resistant durable material. Ducting which may degrade or corrode during the expected life of the structure shall not be permitted. The system shall be fully compatible with the prestressing anchorages, couplers and other details. Where ducts are non-conductive, metal parts of anchorages shall be electrically bonded to the adjacent reinforcement at each end of the tendon and electrical continuity of the structure over the length of the tendon shall be confirmed by testing.

The following air pressure tests shall be carried out on site unless specified otherwise in Appendix 17/6.

Duct Assembly Verification Tests

Each complete duct system including vents, anchorages, anchorage caps, and where appropriate couplers and their connections, shall be air-pressure tested before concreting. Testing to a pressure of 0.01N/mm^2 unless otherwise specified in Appendix 17/6, shall demonstrate that the system is undamaged and has been correctly assembled. The testing shall demonstrate that a loss of pressure no greater than 10% occurs after 5 minutes, unless specified otherwise in Appendix 17/6.

The minimum manufactured wall thickness of ducting for internal tendons shall be 2 mm. The duct rigidity and type and spacing of fixings and supports shall be such as to maintain line, position and cross section shape during concreting. Local deformation of the duct at supports shall be avoided.

For external tendons the minimum wall thickness shall be 4 mm for durability, or such thicker wall as required to withstand grouting pressures of the particular duct configuration.

The Contractor shall provide evidence of testing to demonstrate the following requirements:

(i) Wall thickness of ducts for tendons after tensioning of the tendons shall be not less

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than 1.5mm unless specified otherwise in Appendix 17/6.

(ii) (11/03) For internal tendons the duct shall transmit full bond strength from the tendons to the surrounding concrete over a length no greater than 50-100 duct diameters or other such requirement as given in Appendix 17/6.

(iii) (11/03) The duct system shall comply, as a minimum, with the International Federation for Structural Concrete (*fib*) recommendations (Technical Report, Bulletin No. 7) for 'Corrugated plastic ducts for internal bonded post-tensioning', and with other requirements of this Clause.

Vents providing an air passage of at least 15 mm internal diameter shall be provided at the anchorages and in the troughs and crests and beyond each intermediate crest in the direction of flow of the grout at the point where the duct is one half diameter lower than the crest, (but no further than 1m from the crest), unless otherwise described in Appendix 17/6. The maximum spacing of vents shall be 15m unless specified otherwise in Appendix 17/6.

The vent diameter and spacing may be varied in full-scale trials demonstrating the suitability of alternatives. The vents shall be rigidly connected to the ducts, and shall be capable of being closed and re-opened. Holes in the ducts shall be at least the internal diameter of the vents and shall be formed before pressure testing.

For external tendons the arrangement and detailing of the vents at positions within deflectors/diaphragms shall be proven by detailed testing.

Vents on each duct shall be identified by labelling and shall be protected against damage at all times.

Vents at high points shall extend to a minimum of 500 mm above the highest point on the duct profile unless described otherwise in Appendix 17/6.

Grouting Equipment

4 (11/03) Grouting equipment shall consist of a mixer, a storage reservoir and a pump with all the necessary connection hoses, valves, measuring devices for water, dry materials, admixtures and testing equipment.

The mixing equipment shall be capable of producing a grout of homogeneous consistency and shall be capable of providing a continuous supply to the injection equipment. The capacity of the equipment shall be such that each duct can be filled and vented without interruption and at the required rate of injection.

The injection equipment shall be capable of continuous operation and shall include a system for recirculating the grout when grouting is not in progress.

The equipment shall provide a constant delivery pressure; it shall have two pressure gauges and a pressure relief valve to prevent pressures exceeding 1 N/mm^2. All piping to the grout pump shall have as few bends, valves and changes in diameter as possible, and shall incorporate a sampling Tee with a locking-off valve.

The equipment shall be capable of maintaining pressure on completely grouted ducts and shall be fitted with a valve that can be locked off without loss of pressure in the duct.

During the grouting operation the Contractor shall provide adequate flushing-out plant to facilitate complete removal of the grout in the event of a breakdown of the grouting equipment or other disruption before the grouting operation has been completed. The Contractor shall demonstrate that this equipment is in full working order.

All equipment shall be kept free from build-up of adhering materials.

(11/03) **Batching and Mixing of Grouts**

5 (11/03) All materials shall be batched by mass except the mixing water and liquid admixtures which may be batched by mass or by volume. Bagged materials shall be weighed before use, unless clearly weight marked with stated tolerance. The accuracy of batching shall be or have been (in case of pre-bagged materials):

± 2% for dry materials, cement and admixtures

± 1% for mixing water

of the quantities specified. The total amount of mixing water shall include the water content of liquid admixtures.

Depending upon environmental or material influence (eg temperature, configuration of the tendon and properties of the materials used), the water/cement ratio shall be kept as low as possible having regard to the required plastic properties of the grout. Actual water/cement ratios shall be recorded.

The material shall be mixed to produce a homogeneous grout and kept in slow continuous agitation until pumped into the duct. Unless manufacturers specify otherwise, water shall be added to the mixer first, followed by the dry materials which may be added as a whole or in part in sequence until the total quantities are added. The minimum mixing time determined from grouting trials shall be adhered to.

The temperature of freshly mixed grout shall be between 5°C and 30°C. The maximum temperature may be increased provided trials demonstrate that the grout meets the requirements of sub-Clause 1711.8.

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Injecting Grout

6 (11/03) A check shall be made to ensure that the ducts, vents, inlets and outlets are capable of accepting injection of the grout. This check shall be achieved by blowing through the system with dry, oil-free air and testing each vent in turn.

Any water in the ducts shall be removed before grouting operations commence.

Grouting of the ducts shall be carried out within 28 days of installation of the tendon or as soon as is practicable thereafter, in which case additional measures shall be taken to avoid corrosion of the prestressing steel. The Overseeing Organisation's written agreement to commence grouting operations shall be obtained. Injection shall be continuous and the rate of injection slow enough to avoid segregation of the grout.

Grout shall only be injected from one end of the duct.

The method of injecting grout shall ensure filling of the ducts and that the tendons are surrounded by grout. Grout shall be allowed to flow from each vent and the remote end of the duct until its fluidity is visually equivalent to that of the grout being injected. In the event of disagreement, testing may be carried out in accordance with sub-Clause 1711.8.

Following this, a further 5 litres of grout at each vent, or such other requirement of Appendix 17/6, shall be vented into a clean receptacle and then discarded. The opening shall be firmly closed. All vents shall be closed in a similar manner one after another in the direction of the flow except that at intermediate crests the vents immediately downstream shall be closed before their associated crest vent.

The injection tubes shall then be sealed off under pressure with a pressure of 0.5 N/mm^2 being maintained for at least one minute. Grout vents at high points shall be reopened immediately after 1 minute, while the grout is still fluid. Any escape of air, water or grout shall be recorded and reported immediately to the Overseeing Organisation. A further pumping of grout shall then be carried out to expel bleed water – and/or entrapped air. This shall be carried out with the vents open one at a time sequentially in the direction of grouting with a further 5 litres being released at each vent. In the event of disagreement over the quality of the vented grout, testing shall be undertaken immediately by the Contractor.

The injection tubes shall then be sealed off under pressure, with a pressure of 0.5 N/mm^2 being maintained for at least one minute.

The filled ducts shall not be subjected to shock or vibration for at least 24 hours from the time of grouting.

When the grout has set, the grout vents shall be temporarily reopened. If voids are apparent on inspecting vents at end caps, the Overseeing Organisation may require all or some of the end caps to be removed to demonstrate that they are satisfactorily filled with grout. End caps which have been removed shall then be replaced and permanently sealed against ingress of contaminants, such sealing to be proved to the Overseeing Organisation.

If the method of demonstrating filling of the anchorage caps involves their removal, a photographic record shall be made by the Contractor. The record shall clearly identify the individual anchorages, and shall be included in the report to the Overseeing Organisation.

If, in the opinion of the Overseeing Organisation, there is doubt that the ducts or any part of the system are not satisfactorily filled with grout, the Overseeing Organisation may require investigations to be carried out.

The Contractor shall keep full records of grouting for each duct in accordance with the certification scheme requirements for the installation of post-tensioning systems. Copies of these records shall be supplied to the Overseeing Organisation within 24 hours of completing grouting to each duct.

On completion of grouting, grout vents shall be positively sealed and waterproofed by a means separate from the concrete waterproofing.

Grouting During Cold Weather

7 (11/03) When the ambient temperature is expected to fall below 5°C, accurate records shall be kept by the Contractor of the maximum and minimum air temperatures, and the temperatures of the structural elements adjacent to the ducts to be grouted. No materials containing frost or ice shall be used, and the ducts and equipment shall be completely free of frost and ice.

Grout shall not be placed when the temperature of the structural elements adjacent to the ducts is below 4°C, or is likely to fall below 4°C during the following 48 hours, unless the element is heated so as to maintain the temperature of the placed grout above 5°C for at least 48 hours.

Methods of heating shall be to the acceptance of the Overseeing Organisation.

Ducts shall not be warmed with steam.

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Properties of Grout

8 (05/04) The following criteria shall apply:

Fluidity

When tested by the method specified in sub-Clause 1711.9, the fluidity of the grout shall meet the criteria given in Table 17/4. Additionally, the fluidity (flow cone passage time) at outlets shall not vary from that of the injected grout by more than 20%.

TABLE 17/4: (05/04) **Test Requirements for Fluidity of Grout**

Test Method	Cone
Fluidity immediately after mixing	≤25 s (see note)
Fluidity at the end of the injection period subject to a minimum of 30 minutes after mixing*	≤25 s (see note)
Fluidity at duct outlet	≥10 s
* Mixing time shall be measured from the time when all of the materials are in the mixer. For pre-bagged grout the minimum time shall be 90 minutes.	
NOTE: For grouts prepared in some mixers which have a high shear mixing action, the upper limits given in Table 17/4 may be increased to 50 s. The mixer and these limits shall be subject to the acceptance of the Overseeing Organisation.	

Bleeding

When tested by the method referred to in sub-Clause 1711.9 the bleeding for grout shall be less than 1% of the initial volume of the grout and the average of 4 successive results shall be less than 0.3%. Testing shall be carried out at 24 hours.

Volume Change

The volume change assessed may be either an increase or decrease. When tested in accordance with the method referred to in sub-Clause 1711.9 the volume change of grout shall be within the range - 0% to + 5%.

Strength

The compressive strength of 100 mm cubes made of the grout shall exceed 27 N/mm^2 at 7 days. Cubes shall be made, cured and tested in accordance with BS EN 12390-1 and BS EN 123900-3.

Sieve Test

The grout shall contain no lumps. This shall be verified by testing as referred to in sub-Clause 1711.9.

Sedimentation Test

When tested by the method referred to in sub-Clause 1711.9 the grout shall not exhibit variation in density from top to bottom of a single test sample in excess of 5%.

Testing of Grout

9 (05/04) General. Suitability and acceptance tests for the properties of grout shall be determined in accordance with the Concrete Society Technical Report 47 "Durable Bonded Post-Tensioned Concrete Bridges" 2nd edition. The testing requirements are summarised in Table 17/5.

TABLE 17/5: (05/04) **Minimum Test Requirements for Grout**

Suitability Testing	
Fluidity	Sampled immediately after mixing, one test. After estimated time to grout duct or minimum of 90 mins from initial mixing. Two tests averaged in both cases.
Bleed Volume change Sedimentation Strength	Each sampled immediately after mixing, 3 tests averaged.
Acceptance Testing	
Fluidity	Sampled immediately after mixing, one test from mixer. After flow through duct, one test from each anchorage outlet. On completion, one test from the mixer.
Bleed Volume Change Strength	One tests per day or one per 1.5 m^3 of grout unless otherwise agreed by the Overseeing Organisation.
Sedimentation	One test per day for site bateched grout, or one test per pre-bagged supplied batch (by manufacturer's reference number); subject to a minimum of one test per continuous grouting operation.

Admixtures

10 (11/03) The following criteria shall apply:

General

Admixtures shall be used where required to achieve a low water/cement ratio and impart good fluidity, minimum bleed and volume stability or expansion to the grout to comply with sub-Clause 1711.8. For site batched grout admixtures should be added on site during the mixing process and used in accordance with the manufacturer's recommendations. For pre-bagged grout the admixtures shall form a pre-blended component.

Types

Admixtures are divided into two types, expanding and non-expanding and they may be used to obtain the required grout performance. Admixtures used in combination shall be checked for compatibility by the Contractor, and reported to the Overseeing Organisation for acceptance.

Chemical Composition

Admixtures shall not contain substances in quantities that will adversely affect the grout or cause the grout to promote corrosion of the prestressing steel by rusting, pitting, stress corrosion or hydrogen embrittlement.

Material requirements

The admixture shall not segregate and shall be uniform in colour. The composition shall not change and the supplier shall operate a quality system complying with BS EN ISO 9001. The quality system shall be certified by a third party accredited by an appropriate organisation in accordance with sub-Clauses 105.3 and 105.4.

Where appropriate, admixtures shall comply with BS EN 934-4. Other admixtures shall be permitted provided they satisfy Clause 8 of BS EN 934-2 and full account is taken of their effects on the finished product and their fitness for purpose. Data on their suitability, including previous experience with such materials, shall be made available and records of the details and performance of such materials shall be maintained.

It should be noted that additional information beyond that required by Clause 8 of BS EN 934-2 must be provided by the manufacturer for admixtures bearing CE marking (see ZA.2.2 and ZA.3 of BS EN 934-2).

Dosage

The optimum dosage of any admixture shall be determined by trial mixes with the cement to be used in the grout. This dosage shall be expressed as percent by mass of the cement. It shall be within the range recommended by the supplier and shall not exceed 5% by mass of the cement. The method of measuring dosage and checking weights of pre-packed dry materials shall comply with sub-Clause 1711.5 or as otherwise agreed with the Overseeing Organisation.

1712 (05/01) Reinforcement - Materials

(05/02) **Hot Rolled and Cold Worked Carbon Steel Bars**

1 (05/02) All steel reinforcement specified shall comply with BS 4449 or BS 4483 and shall be cut and bent in compliance with BS 8666 and shall be obtained from a firm holding a valid CARES (or fully equivalent scheme) certificate of approval.

2 (05/02) Hot rolled and cold worked carbon steel bars shall comply with BS 4449 except that no bar shall contain a flash weld.

Hard Drawn Steel Wire

3 Hard drawn mild steel wire shall comply with BS 4482.

Steel Fabric

4 Steel fabric reinforcement shall comply with BS 4483 and shall be delivered to the Site in flat mats or pre-bent.

(05/02) **Stainless Steel Reinforcement**

5 (05/04) All stainless steel reinforcement shall comply with BS 6744 and shall be cut and bent in compliance with BS 8666 and shall be obtained from companies holding valid CARES (or fully equivalent scheme) certificates of approval for the production and supply of stainless reinforcement.

6 (05/02) Stainless steel reinforcement shall be to the specified material strength grade in BS 6744.

Bond Strength

7 (05/02) The classification of deformed carbon steel bars as Type 1 or 2 for bond strength shall be in accordance with BS 4449. The type of deformed carbon steel bar shall be as described in Appendix 17/4.

Stainless steel reinforcement shall be plain or ribbed bar in accordance with BS 6744 and shall be as described in Appendix 17/4.

1713 (05/02) Carbon Steel Reinforcement and Stainless Steel Reinforcement - Bar Schedule Dimensions - Cutting and Bending

1 (05/02) The bar schedules are based on the dimensions of the concrete and the nominal cover to the reinforcement shown on the Drawings. The reinforcement shall be cut and bent within the tolerances given in BS 8666 but this shall not relieve the Contractor of his responsibility for the correct fit of the reinforcement and the achievement of the required cover as described in Clause 1714.

Bending of reinforcement at temperatures below 5°C or in excess of 100°C shall not be carried out.

Re-bending of grade 460 carbon steel bars on site shall not to be permitted. Re-bending of grade 250 bars not exceeding 12 mm may be carried out.

Re-bending of stainless steel reinforcement bars on site shall not be permitted.

Site storage of reinforcement should ensure that it is clear of the ground and covered with a waterproof sheeting or fixed cover, in order to reduce contamination and excess corrosion prior to placement.

1714 Reinforcement - Fixing

1 (05/04) Reinforcement shall be secured against displacement. Unless specified otherwise, the actual concrete achieved cover shall be not less than the required minimum cover derived from the exposure class Tables in BS 8500-1, and including any allowance for longer durability required under clause A5 of BS 8500-1. The maximum achieved cover shall not be more than the nominal cover as defined in BS 8500-1, including the stated fixing tolerance Δc.

Bars in inner layers shall be located as shown on the Drawings; they shall be in close contact with the bars of the outer layer, unless otherwise indicated. Welding of carbon steel reinforcing bars for fixing purposes shall be in accordance with Clause 1717.

Welding of stainless steel reinforcement bars shall not be permitted.

Cover blocks shall be of comparable strength, durability and appearance to the surrounding concrete. They shall match the mix proportions of the adjacent material so far as is practicable. They shall ensure that the reinforcement is correctly positioned and shall be as small as possible consistent with their purpose, and designed so that they will not overturn or be displaced when the concrete is placed. Reinforcement spacers and chairs should be produced and fixed in accordance with the Concrete Society report CS 101.

Wire cast in the block for the purpose of tying it to the reinforcement shall be as described below.

Spacer blocks (categorised as heavy in the Concrete Society Report CS101) should be factory produced. Site produced concrete or mortar spacers shall not be used.

Projecting ends of ties or clips shall not encroach into the concrete cover. Tying wires shall be 1.2 mm diameter stainless steel wire throughout the structure excepting any locations as described in Appendix 17/4 where 1.6 mm soft annealed iron wire may be used. Stainless steel tying wire shall be used when tying stainless steel reinforcement.

The Contractor shall provide access and carry out a cover measurement survey of all reinforced concrete surfaces within the 24-hour period following the removal of formwork. The cover measurement survey shall be carried out on a 500 mm grid over the whole structure in general accordance with BA 35 (DMRB 3.3).

1715 Reinforcement - Surface Condition

1 (05/01) Immediately before concrete is placed around it, reinforcement shall be free from mud, oil, paint, retarder, release agent, loose rust, loose mill scale, snow, ice, grease or any other substance that can be shown to have an adverse chemical effect on the steel or concrete, or to reduce the bond between the steel and the concrete.

1716 (05/01) Reinforcement - Laps and Joints

1 Laps and joints shall be made only where shown on the Drawings, except in the case where additional laps or splice bars are required and the Overseeing Organisation's approval has been obtained.

2 Where reinforcing bars are required to be coupled the coupling system shall have a current British Board of Agrément Roads and Bridges Certificate or CARES Certificate of Product Assessment and shall be sourced from a firm holding relevant valid CARES (or fully equivalent scheme) certificate of approval. Couplers shall comply with cover requirements of sub-Clause 1714.1.

1717 Reinforcement - Welding

General

1 (05/02) Welded reinforcement, other than steel fabric reinforcement, shall not be incorporated in the Permanent Works unless permitted in Appendix 17/4. When required, the Contractor shall demonstrate that at each location the fatigue life, durability and other properties of the member are not adversely affected by the proposal.

Site welding of stainless steel reinforcement bars shall not be permitted.

(05/02) Flash Butt Welding for Carbon Steel

2 (05/01) Flash butt welding shall only be carried out with an appropriate combination of flashing, heating, upsetting and annealing and subject to the demonstration of the satisfactory performance of trial joints. Only those machines that automatically control this cycle of operations shall be used.

(05/02) Manual Metal-arc Welding for Carbon Steel

3 (05/01) Metal-arc welding shall be carried out in accordance with BS 7123 and the recommendations of the reinforcement manufacturer, subject to the demonstration of the satisfactory performance of trial joints.

(05/02) Other Methods of Welding for Carbon Steel

4 (05/01) Other methods of welding may be used subject to the demonstration of the satisfactory performance of trial joints.

Strength of Structural Welded Joints

5 (05/02) The strength of all structural welded joints shall be assessed following tests on trial joints to establish the minimum specified mechanical properties of the joint. Tests shall be carried out by an independent testing body as specified in BS 8666.

1718 Prestressing Tendons - Materials

Steel Wire

1 (05/01) Steel wire shall comply with BS 5896.

Cold Worked High Tensile Alloy Bar

2 Cold worked high tensile alloy steel bars for prestressed concrete shall comply with BS 4486.

Stress-relieved Seven-wire Strand

3 (05/01) Stress-relieved seven-wire strand shall comply with BS 5896 or have properties that are not inferior.

Sampling and Testing

4 (05/01) When it is proposed to use super strand complying with BS 5896 : Table 6, or other than the lowest strength 3, 4, 5, 6 or 7 mm diameter wires complying with BS 5896 Tables 4 or 5 the following shall apply:

(i) A sample shall be taken from each reel of material proposed for use in the Works.

(ii) A reel shall only be accepted if both the breaking load and the 0.1% proof load of the sample exceeds the specified characteristic loads given in Tables 4 or 6. In the case of Table 5 this requirement shall apply to the breaking load and the load at 1% elongation.

5 (05/04) Where scheduled in Appendix 1/5, the Contractor shall arrange for samples of the steel intended for use in the Permanent Works to be tested at a testing laboratory appropriately accredited by an appropriate organisation in accordance with sub-Clauses 105.3 and 105.4.

1719 Prestressing Tendons - Handling and Storage

1 Care shall be taken to avoid mechanically damaging, work-hardening or heating prestressing tendons while handling. All prestressing tendons shall be stored clear of the ground and protected from the weather, from splashes from any other materials, and from splashes from the cutting operation of an oxy-acetylene torch, or arc-welding processes in the vicinity.

In no circumstances shall prestressing tendons after manufacture be subjected to any welding operation, or heat treatment or metallic coating such as galvanizing. This does not preclude cutting as described in Clause 1722.

1720 Prestressing Tendons - Surface Condition

1 (05/01) Prestressing tendons and internal and external surfaces of sheaths or ducts shall be clean and free from pitting at the time of incorporation in the work. Slight surface rusting is acceptable.

1721 Prestressing Tendons - Straightness

Wire

1 Low relaxation and normal relaxation wire shall be in coils of sufficiently large diameter to ensure that the wire pays off straight, except that in cases where straight as-drawn wire is not essential, wire in small-diameter coils (corresponding to the diameter of the blocks in the drawing machine) may be used.

Strand

2 Prestressing strand, however manufactured, shall be in coils of sufficiently large diameter to ensure that the strand pays off straight.

Bars

3 (05/01) Prestressing bars as delivered shall be straight. Any small adjustments for straightness that are necessary on Site shall be made by hand. Bars bent in the threaded portion shall be rejected. Any straightening of bars shall be carried out cold but at a temperature of not less than 5°C. Any necessary warming shall be by means of steam or hot water.

1722 Prestressing Tendons - Cutting

1 All cutting of wire, strand or bar shall be carried out using either:

(i) a high-speed abrasive cutting wheel, friction saw or equivalent mechanical method at not less than one diameter from the anchor; or

(ii) an oxy-acetylene cutting flame, using excess oxygen to ensure a cutting rather than a melting action, not less than 75 mm from the anchor. The temperature of the tendon adjacent to the anchor shall not be greater than 200°C. Care shall be taken that neither the flame nor splashes come into contact with the anchorages or tendons.

1723 Prestressing Tendons - Positioning of Tendons, Sheaths and Duct Formers

1 Tendons, sheaths and duct formers shall be accurately located and maintained in position both vertically and horizontally as shown on the Drawings. Unless otherwise described in Appendix 17/4 the tolerance in the location of the centre line of sheath or duct shall be ± 5 mm.

Where tendons are described in the Contract as debonded from the concrete they shall be covered with suitable sleeves. The ends of the sleeves shall be taped to the tendon to prevent the ingress of grout.

Joints in sheaths shall be securely taped to prevent penetration of the duct by concrete or laitance, and ends of ducts shall be sealed and protected after the stressing and grouting operations. Joints in adjacent sheaths shall be spaced at least 300 mm apart.

1724 Prestressing Tendons - Tensioning

General

1 All wires, strands or bars stressed in one operation shall be taken, where possible, from the same parcel. Each cable shall be tagged with its number from which the coil numbers of the steel used can be identified. Cables shall not be kinked or twisted. Individual wires and strands for which extensions are to be measured shall be readily identifiable at each end of the member. No strand that has become unravelled shall be used.

Tensioning Apparatus

2 The tensioning apparatus shall meet the following general requirements:

(i) The means of attachment of the tendon to the jack or tensioning device shall be safe and secure.

(ii) Where two or more wires or strands are stressed simultaneously, they shall be approximately of equal length between anchorage points at the datum of load and extension measurement. The degree of variation shall be small compared with the expected extension.

(iii) The tensioning apparatus shall be such that a controlled total force is imposed gradually and no dangerous secondary stresses are induced in the tendons, anchorage or concrete.

(iv) The force in the tendons during tensioning shall be measured by direct-reading load cells or obtained indirectly from gauges fitted in the hydraulic system to determine the pressure in the jacks. Facilities shall be provided for the measurement of the extension of the tendon and of any movement of the tendon in the gripping devices. The load measuring device shall be calibrated to an accuracy within ± 2% and checked at frequent intervals.

Elongation of the tendon shall be measured to an accuracy within 2% or 2 mm, whichever is the lesser.

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(v) The tensioning equipment shall be calibrated before the tensioning operation and subsequently at frequent intervals.

Pretensioning

3 Where pretensioning methods are used, the tension shall be fully maintained by some positive means during the period between tensioning and transfer. The transfer of stress shall take place slowly to minimize shock.

(i) Straight tendons. In the long-line method of pretensioning, sufficient locator plates shall be distributed throughout the length of the bed to ensure that the wires or strands are maintained in their proper position during concreting. Where a number of units are made in line, they shall be free to slide in the direction of their length and thus permit transfer of the prestressing force to the concrete along the whole line.

In the individual mould system, the moulds shall be sufficiently rigid to provide the reaction to the prestressing force without distortion.

(ii) (05/04) Deflected tendons. Where possible, the mechanisms for holding down or holding up tendons shall ensure that the part in contact with the tendon is free to move in the line of the tendon so that frictional losses are nullified. If, however, a system is used that develops a frictional force, this force shall be determined by test and due allowance made.

For single tendons the deflector in contact with the tendon shall have a radius of not less than 5 times the tendon diameter for wire or 10 times the tendon diameter for strand, and the total angle of deflection shall not exceed 15°.

The transfer of the prestressing force to the concrete shall be effected in conjunction with the release of hold-down and hold-up forces.

Unless otherwise described in Appendix 17/4, concrete shall not be stressed until it has reached at least the age at which 2 test cubes taken from it attain the specified transfer strength. The test cubes shall be made and tested as described in BS EN 12390-2 and BS EN 12390-3 respectively. They shall be cured in similar conditions to the concrete to which they relate. The Contractor shall cast and test sufficient cubes to demonstrate that the required strength of the concrete at transfer has been reached.

Post-tensioning

4 (i) (05/01) Arrangement of tendons. Where wires, strands or bars in a tendon are not stressed simultaneously, the use of spacers shall be in accordance with the recommendations of the system manufacturer.

(ii) Anchorages. Anchorages shall be tested in accordance with BS 4447.

For each anchorage system used in the Works, the characteristic value for anchorage efficiency shall be not less than 90%.

Proprietary anchorages shall be handled and used strictly in accordance with the manufacturer's instructions and recommendations.

(iii) Deflected tendons. The deflector in contact with the tendon shall have a radius of not less than 50 times the diameter of the tendon, and the total angle of deflection shall not exceed 15°.

(iv) (05/04) Tensioning procedure. Before tensioning, the Contractor shall demonstrate that all tendons are free to move in the ducts unless the geometry of the ducts makes this impracticable. Tensioning shall be carried out in such a manner that the stress in the tendons increases at a gradual and steady rate. Tensioning shall not be carried out at a temperature below 0°C.

Unless otherwise described in Appendix 17/4, concrete shall not be stressed until it has reached at least the age at which 2 test cubes taken from it attain the specified transfer strength. The test cubes shall be made and tested as described in BS EN 12390-2 and BS EN 12390-3 respectively. They shall be cured in similar conditions to the concrete to which they relate. The Contractor shall cast and test sufficient cubes to demonstrate that the required strength of the concrete at transfer has been reached.

The Contractor shall ensure that those carrying out the stressing are provided with particulars of the required tendon loads, order of stressing and extensions. Allowance shall be made during stressing for the

friction in the jack and in the anchorage, although the former is not necessary when using load cells, and for draw-in of the tendon during anchoring.

Stressing shall continue until the required extension and tendon load are reached.

The extension shall allow for any draw-in of the tendon occurring at a non-jacking end, but measurement shall not commence until any slack in the tendon has been taken up.

Immediately after anchoring, the forces in the prestressing tendons shall not exceed 70% of their characteristic strength. During stressing the value may exceed 70% of their characteristic strength but shall not exceed 80%.

After the tendons have been anchored, the force exerted by the tensioning apparatus shall be decreased gradually and steadily so as to avoid shock to the tendon or the anchorage. Full records shall be kept of all tensioning operations, including the measured extensions, pressure-gauge or load-cell readings, and the amount of draw-in at each anchorage. When requested copies of these records shall be provided within 24 hours of each tensioning operation.

Tendons shall not be cut within 3 days of their being grouted.

1725 Prestressing Tendons - Protection and Bond

1 The prestressing tendons shall be protected in their permanent positions from both mechanical damage and corrosion as described in Appendix 17/4.

1726 Stainless Steel Dowels - Materials

1 (05/02) Dowels shall be made from Steel Designation 1.4429 or 1.4436 and Grade 200 or 500 steel bars complying with BS 6744.

1727 Inspection and Testing of Structures and Components

General

1 Inspection and testing of structures and components shall be carried out as described in Appendix 17/4.

Concreting operations shall not displace reinforcement, tendon ducts, tendon anchorages or formwork, or damage the faces of formwork.

Concrete shall be thoroughly compacted by vibration during the operation of placing, and thoroughly worked around the reinforcement, tendons or duct formers, around embedded fixtures and into corners of the formwork to form a solid mass free from voids. When vibrators are used to compact the concrete, vibration shall be applied continuously during the placing of each batch of concrete until the expulsion of air has practically ceased and in a manner that does not promote segregation of the ingredients.

Particular care shall be taken when concreting bridge decks of substantial thickness to avoid layering of concrete, and the whole thickness shall be placed in one pass. In deck slabs where void formers are used, adequate means to prevent flotation shall be employed and care taken to ensure adequate compaction of the concrete placed beneath the void formers.

A sufficient number of vibrators in serviceable condition shall be on site to ensure that spare equipment is always available in the event of breakdowns.

Vibration shall not be applied by way of the reinforcement. Where vibrators of the immersion type are used, contact with reinforcement and inserts shall be avoided as far as is practicable.

Concrete shall not be subjected to disturbance between 4 hours and 24 hours after compaction except that re-compaction of the upper layers of deep lifts to prevent or anneal settlement cracking may be carried out. Whenever vibration has to be applied externally, the design of formwork and disposition of vibrators shall ensure efficient compaction and the avoidance of surface blemishes.

There shall be no excess water on the top surface on completion of compaction.

Striking of Formwork

4 (i) (05/01) General. Formwork shall be removed in a manner not to damage the concrete, and at times to suit the requirements for its curing and to prevent restraint that may arise from elastic shortening, shrinkage or creep.

(ii) (05/02) Striking period. Where the concrete compressive strength is confirmed by tests on concrete cubes stored under conditions that simulate the field conditions, formwork supporting concrete in bending may be struck when the cube strength is 10 N/mm² or three times the stress to which it will be subjected, whichever is the greater.

For ordinary structural concrete made with Portland cement (CEM I) or sulfate-resisting Portland cement (SRPC) of strength class 42.5 or above, in the absence of control cubes the period before striking shall be in accordance with the minimum periods given in Table 17/12.

TABLE 17/12: (05/02) **Minimum Period Before Striking Formwork (CEM I or SRPC Concrete)**

	Minimum Period Before Striking		
	Surface temperature of concrete:		
	16°C	**7°C**	**t°C (any temperature between 0°C and 25°C)**
Vertical formwork to columns, walls and large beams	12 hours	18 hours	300 hours t + 10
Soffit formwork to slabs	4 days	6 days	100 days t + 10
Props to slabs	10 days	15 days	250 days t + 10
Soffit formwork to Beams	9 days	14 days	230 days t + 10
Props to beams	14 days	21 days	360 days t + 10

Where surface temperatures of concrete fall outside or are likely to fall outside the above temperature ranges agreement should be reached between the Contractor and Overseeing Organisation on appropriate striking times.

Curing of Concrete

5 (i) (05/02) Curing methods. Immediately after compaction and thereafter for the curing time, except where elevated temperature curing is used, concrete shall be protected against harmful effects of weather, including rain, rapid temperature changes, frost, and from drying out. The method of curing shall provide a suitable environment for the concrete to mature and prevent harmful loss of moisture.

The curing time shall be the number of days given in Table 17/13 unless the average surface temperature of the concrete during the required number of days falls below 10°C, in which case the period of curing shall be extended until the maturity of the concrete reaches the value given in the table.

The Contractor shall keep records of all curing liquids, compounds and membranes and their subsequent removal from the areas scheduled in Appendix 17/2. Where the Contractor proposes to use a curing liquid, compound or membrane on surfaces on which a waterproofing system is to be laid, it shall be completely removable.

Where the Contractor proposes the use of a curing liquid, compound or membrane on surfaces scheduled in Appendix 17/2, it shall be of a film type that fully degrades by exposure to ultra-violet light without leaving any residue that is detrimental to the surface impregnation of the concrete.

TABLE 17/13: (05/02) **Minimum Periods of Normal Curing for Different Types of Cement**

Conditions under which concrete is maturing	**Number of days (where the average surface temperature of the concrete exceeds 10°C during the whole period)**			**Equivalent maturity (degree hours) calculated as the age of the concrete in hours multiplied by the number of degrees Celsius by which the average surface temperature of the concrete exceeds -10°C**		
	Other*	SRPC	PC	Other*	SRPC	PC
1. Hot weather or drying winds	7	4	3	3500	2000	1500
2. Conditions not covered by 1	4	3	2	2000	1500	1000

NOTE. Other* includes all permitted cements except PC and SRPC.
(05/02) PC = Portland cement (CEM I).
SRPC = Sulfate-resisting Portland cement.

(ii) (05/02) Accelerated curing. Elevated-temperature curing as described below may be used only with Portland cement (CEM I) or sulfate-resisting Portland cement.

(a) The formwork may be generally heated to no more than 20°C prior to the placing of concrete.

(b) Once placing is complete the concrete shall be left for 4 hours without additional heating. The concrete temperature can then be raised at a maximum rate of 10°C per ½hour.

(c) The concrete temperature shall at no time exceed 70°C.

(d) The rate of subsequent cooling shall not exceed the rate of heating.

(e) Cubes shall be manufactured and cured under identical conditions to those to which the concrete is subjected.

The use of accelerated curing methods for concrete containing other types of cement or any admixture shall not be used.

Cold Weather Work

6 When concrete is placed at air temperatures below 2°C, the following requirements shall be met:

(i) The aggregates and water used in the mix shall be free from snow, ice and frost.

(ii) The surface temperature of the concrete at the time of placing shall be at least 5°C and shall not exceed 30°C.

(iii) The surface temperature of the concrete shall be maintained at not less than 5°C until the concrete reaches a strength of 5 N/mm² as determined by tests on cubes that were cured under identical conditions to the structural concrete.

(iv) Before placing concrete, the formwork, reinforcement, prestressing steel and any surface with which the fresh concrete will be in contact shall be free from snow, ice and frost.

(v) Cement shall not be allowed to come into contact with water at a temperature greater than 60°C.

Hot Weather Work

7 During hot weather the Contractor shall ensure that the constituent materials of the concrete are sufficiently cool to prevent the concrete from stiffening in the interval between its discharge from the mixer and compaction in its final position.

Cement shall not be allowed to come into contact with water at a temperature greater than 60°C.

Precast Concrete Construction

8 (i) (05/01) Manufacture off the Site. The Contractor shall give reasonable notice to the Overseeing Organisation in advance of the date of commencement of manufacture and casting of each type of member.

A copy of all 28-day cube test results relating to the work shall be made available.

For all prestressed members, the Contractor shall obtain, not more than 7 days after the transfer of stress, a certificate showing the force and extension in the tendons after they were anchored, the strength and age of test cubes cast as described in sub-Clause 1724.4(iv) and the minimum age in hours of the concrete at the time the stress was applied to the member.

For all prestressed pretensioned members the length, cross-section dimensions and straightness of precast concrete shall be measured at 28 ± 2 days after casting. Unless otherwise stated, and notwithstanding the requirements of (iv) below, the allowable dimensional variations shall not exceed the following:

Length	Variation
Up to 3 m	± 6 mm
3 to 4.5 m	± 9 mm
4.5 to 6 m	± 12 mm
Additional for every subsequent 6 m	± 6 mm
Cross section (each direction)	
Up to 500 mm	± 6 mm
500 to 750 mm	± 9 mm
Additional for every subsequent 250 mm	± 3 mm
Straightness or bow (deviation from intended line)	
Up to 3 m	± 6 mm
3 to 6 m	± 9 mm
6 to 12 m	± 12 mm
Additional for every subsequent 6 m	± 6 mm

The above allowable dimensional variations have not been taken into account in the bar schedules (Clause 1713 refers).

Where tests are to be carried out, no members to which the tests relate shall be dispatched to the Site until the tests have been satisfactorily completed.

All members shall be indelibly marked to show the member mark as shown on the Drawings, the production line on which they were manufactured, the date on which the concrete was cast and, if they are of symmetrical section, the face that 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.

Unless otherwise specified the vibrated top surface of precast concrete members which will subsequently receive in situ concrete shall be further prepared by one of the following methods as shown on the Drawings:

Class 1 surface preparation,

The surface finish shall be in accordance with sub-Clause 1 of this Clause.

Class 2 surface preparation,

The hardened surface shall be jetted with air or water to remove laitance and all loose material and no further roughening shall then be carried out (rough as cast).

(ii) Storage. When members are stored, they shall be firmly supported only at the points described in Appendix 17/4. The

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accumulation of trapped water and deleterious matter in the units shall be prevented. Care shall be taken to avoid rust staining and efflorescence.

When a stack is several units high, packings shall be vertically above each other to prevent additional bending stresses in any unit. Where disfigurement would be detrimental, packing pieces shall not discolour or otherwise permanently damage the units.

(iii) Handling and transport. Members shall be lifted or supported only at points described in Appendix 17/4 and shall be handled and placed without impact.

(iv) Assembly and erection. In a composite slab bridge where precast beams are laid side by side with minimal gaps to form a deck:

(a) the difference in soffit level between adjacent units before the in situ concrete is placed shall nowhere exceed 5 mm for units up to 5 m in length or 10 mm for longer units;

(b) the width of the deck soffit shall be within + 25 mm of that shown on the Drawings;

(c) in adjacent spans, the continuity of line of the outside beams shall be maintained;

(d) the width of the gap between individual beams shall not exceed twice the nominal gap shown on the Drawings;

(e) the alignment of transverse holes shall permit the reinforcement or prestressing tendons to be placed without distortion.

The in situ concrete in composite slab bridges shall be placed in such a sequence that the advancing edge of the freshly deposited concrete over the full width of the deck, between longitudinal construction joints, is approximately parallel to the deck supports. Precast beams shall be prevented from moving laterally during the placing of the in situ concrete.

The method of assembly and erection shall comply with any particular requirements in Appendix 17/4.

(v) Forming structural connections. The composition and water/cement ratio of the in situ concrete or mortar used in any connection and in the packing of joints shall be in accordance with the assembly instructions.

Levelling devices shall only be released or removed when the structural connection is complete and has achieved sufficient strength.

(vi) Protection. At all stages of construction, precast concrete units and other concrete associated therewith shall be properly protected to prevent damage to permanently exposed concrete surfaces, especially arrises and decorative features.

1711 (05/01) Concrete - Grouting and Duct Systems for Post-tensioned Tendons

Planning, Trials and Basic Requirements

1 (11/03) Site operations, including duct installation, stressing and grouting, shall be carried out by organisations certificated by CARES in accordance with the requirements of the CARES Scheme for the Supply and Installation of Post-tensioning Systems in Concrete Structures, or an equivalent scheme.

Grouts for protection of prestressing tendons shall be as required in Appendix 17/6 and defined in sub-Clause 1711.2.

The Contractor shall undertake full-scale trials of the grout mix and of the grouting operations as required in the Contract for duct installation, testing, concreting, grouting and any other associated requirements in accordance with the details described in Appendix 17/6. The trials are required to demonstrate that the grouting methods and procedures proposed by the Contractor shall ensure that grout fills the ducts and surrounds the prestressing steel.

The Contractor shall submit for acceptance of the Overseeing Organisation, a detailed method statement, at least 4 weeks prior to use in any trials or in the Works, covering proposed materials, ducts, anchorage and vent arrangements, personnel, equipment, grouting procedures and quality control.

Where full scale trials are required, these shall be commenced at least 56 days before the planned commencement of fixing ducts for prestressing for the permanent works unless specified otherwise in Appendix 17/6. The trials shall incorporate all relevant details of ducts, vents, duct supports, prestressing anchorages and couplers, prestressing strands, grout inlets and outlets. The tendons shall be sufficiently tensioned such that the strands within the duct take up a representative alignment. All systems, methods and materials are to be those proposed for the permanent

works and shall have been submitted to the Overseeing Organisation as part of the detailed method statement required.

After three days the Contractor shall carefully cut or core the trial section to expose cross sections and longitudinal sections of the duct, anchorages and any other locations where required, or as further directed by the Overseeing Organisation, to demonstrate that the duct is satisfactorily grouted. A report shall be prepared by the Contractor giving full details of the trial, testing results and photographs of the exposed sections.

Grouting of the ducts shall be shown to leave no void which has either a dimension greater than 5% of the duct diameter measured in the radial direction of the duct or greater than 200 mm measured in the longitudinal direction of the duct (or appropriate dimension, in the case of oval ducts, anchorages etc) or which poses a risk to the protective system. The location of any voids with respect to grout vents and their adequate grouting and subsequent sealing, and the disposition of the steel tendons within the body of the grout shall be reported in writing by the Contractor to the Overseeing Organisation within 24 days.

Prestressing for the permanent works shall not be permitted without the prior written acceptance of the Overseeing Organisation to grouting procedures and formal acceptance of the results of the grouting trial.

The Contractor shall carry out a materials suitability assessment in accordance with sub-Clause 1711.2.

Grout Materials

2 (11/03) The properties of the grout, made with the materials, and using the plant and personnel proposed for use on site, shall be assessed for suitability for the intended purpose. This assessment shall be carried out sufficiently in advance of grouting operations to enable adjustments to be made in use of materials or plant or personnel.

Grouts shall comply with the requirements in sub-Clause 1711.8. The materials' assessment shall consist of the preparation of the grout, made with the materials, and using the plant and personnel proposed for use on site, and the testing of it in accordance with sub-Clause 1711.9. The preparation shall be carried out under representative conditions of temperature expected on site. If grouting operations are likely to cover different seasons, the assessment shall be carried out for the expected range of temperatures.

No departures from the sources of the materials and procedures approved as a result of satisfactory trials will be permitted without the written approval of the Overseeing Organisation.

Grouts shall consist only of Portland cement (CEM I) complying with BS EN 197-1 Class 42.5N, admixtures complying with sub-Clause 1711.10 and water complying with BS EN 1008. Where proprietary prebagged grout is used it shall be mixed in accordance with the manufacturer's instructions.

Grouts shall not contain a chloride ion content of more than 0.1% by mass of the cement.

Duct Systems

3 (11/03) The system of ducts, duct connectors, grouting connections, vents, vent connections, drains, transitions to anchorages and caps for anchors shall form a complete encapsulation for the tendons which is resistant to the ingress of air and water. Ducts shall be of proven corrosion resistant durable material. Ducting which may degrade or corrode during the expected life of the structure shall not be permitted. The system shall be fully compatible with the prestressing anchorages, couplers and other details. Where ducts are non-conductive, metal parts of anchorages shall be electrically bonded to the adjacent reinforcement at each end of the tendon and electrical continuity of the structure over the length of the tendon shall be confirmed by testing.

The following air pressure tests shall be carried out on site unless specified otherwise in Appendix 17/6.

Duct Assembly Verification Tests

Each complete duct system including vents, anchorages, anchorage caps, and where appropriate couplers and their connections, shall be air-pressure tested before concreting. Testing to a pressure of 0.01N/mm^2 unless otherwise specified in Appendix 17/6, shall demonstrate that the system is undamaged and has been correctly assembled. The testing shall demonstrate that a loss of pressure no greater than 10% occurs after 5 minutes, unless specified otherwise in Appendix 17/6.

The minimum manufactured wall thickness of ducting for internal tendons shall be 2 mm. The duct rigidity and type and spacing of fixings and supports shall be such as to maintain line, position and cross section shape during concreting. Local deformation of the duct at supports shall be avoided.

For external tendons the minimum wall thickness shall be 4 mm for durability, or such thicker wall as required to withstand grouting pressures of the particular duct configuration.

The Contractor shall provide evidence of testing to demonstrate the following requirements:

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(i) Wall thickness of ducts for tendons after tensioning of the tendons shall be not less than 1.5mm unless specified otherwise in Appendix 17/6.

(ii) (11/03) For internal tendons the duct shall transmit full bond strength from the tendons to the surrounding concrete over a length no greater than 50-100 duct diameters or other such requirement as given in Appendix 17/6.

(iii) (11/03) The duct system shall comply, as a minimum, with the International Federation for Structural Concrete (*fib*) recommendations (Technical Report, Bulletin No. 7) for 'Corrugated plastic ducts for internal bonded post-tensioning', and with other requirements of this Clause.

Vents providing an air passage of at least 15 mm internal diameter shall be provided at the anchorages and in the troughs and crests and beyond each intermediate crest in the direction of flow of the grout at the point where the duct is one half diameter lower than the crest, (but no further than 1m from the crest), unless otherwise described in Appendix 17/6. The maximum spacing of vents shall be 15m unless specified otherwise in Appendix 17/6.

The vent diameter and spacing may be varied in full-scale trials demonstrating the suitability of alternatives. The vents shall be rigidly connected to the ducts, and shall be capable of being closed and re-opened. Holes in the ducts shall be at least the internal diameter of the vents and shall be formed before pressure testing.

For external tendons the arrangement and detailing of the vents at positions within deflectors/diaphragms shall be proven by detailed testing.

Vents on each duct shall be identified by labelling and shall be protected against damage at all times.

Vents at high points shall extend to a minimum of 500 mm above the highest point on the duct profile unless described otherwise in Appendix 17/6.

Grouting Equipment

4 (11/03) Grouting equipment shall consist of a mixer, a storage reservoir and a pump with all the necessary connection hoses, valves, measuring devices for water, dry materials, admixtures and testing equipment.

The mixing equipment shall be capable of producing a grout of homogeneous consistency and shall be capable of providing a continuous supply to the injection equipment. The capacity of the equipment shall be such that each duct can be filled and vented without interruption and at the required rate of injection.

The injection equipment shall be capable of continuous operation and shall include a system for recirculating the grout when grouting is not in progress.

The equipment shall provide a constant delivery pressure; it shall have two pressure gauges and a pressure relief valve to prevent pressures exceeding 1 N/mm^2. All piping to the grout pump shall have as few bends, valves and changes in diameter as possible, and shall incorporate a sampling Tee with a locking-off valve.

The equipment shall be capable of maintaining pressure on completely grouted ducts and shall be fitted with a valve that can be locked off without loss of pressure in the duct.

During the grouting operation the Contractor shall provide adequate flushing-out plant to facilitate complete removal of the grout in the event of a breakdown of the grouting equipment or other disruption before the grouting operation has been completed. The Contractor shall demonstrate that this equipment is in full working order.

All equipment shall be kept free from build-up of adhering materials.

(11/03) **Batching and Mixing of Grouts**

5 (11/03) All materials shall be batched by mass except the mixing water and liquid admixtures which may be batched by mass or by volume. Bagged materials shall be weighed before use, unless clearly weight marked with stated tolerance. The accuracy of batching shall be or have been (in case of pre-bagged materials):

± 2% for dry materials, cement and admixtures

± 1% for mixing water

of the quantities specified. The total amount of mixing water shall include the water content of liquid admixtures.

Depending upon environmental or material influence (eg temperature, configuration of the tendon and properties of the materials used), the water/cement ratio shall be kept as low as possible having regard to the required plastic properties of the grout. Actual water/cement ratios shall be recorded.

The material shall be mixed to produce a homogeneous grout and kept in slow continuous agitation until pumped into the duct. Unless manufacturers specify otherwise, water shall be added to the mixer first, followed by the dry materials which may be added as a whole or in part in sequence until the total quantities are added. The minimum mixing time determined from grouting trials shall be adhered to.

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The temperature of freshly mixed grout shall be between 5°C and 30°C. The maximum temperature may be increased provided trials demonstrate that the grout meets the requirements of sub-Clause 1711.8.

Injecting Grout

6 (11/03) A check shall be made to ensure that the ducts, vents, inlets and outlets are capable of accepting injection of the grout. This check shall be achieved by blowing through the system with dry, oil-free air and testing each vent in turn.

Any water in the ducts shall be removed before grouting operations commence.

Grouting of the ducts shall be carried out within 28 days of installation of the tendon or as soon as is practicable thereafter, in which case additional measures shall be taken to avoid corrosion of the prestressing steel. The Overseeing Organisation's written agreement to commence grouting operations shall be obtained. Injection shall be continuous and the rate of injection slow enough to avoid segregation of the grout.

Grout shall only be injected from one end of the duct.

The method of injecting grout shall ensure filling of the ducts and that the tendons are surrounded by grout. Grout shall be allowed to flow from each vent and the remote end of the duct until its fluidity is visually equivalent to that of the grout being injected. In the event of disagreement, testing may be carried out in accordance with sub-Clause 1711.8.

Following this, a further 5 litres of grout at each vent, or such other requirement of Appendix 17/6, shall be vented into a clean receptacle and then discarded. The opening shall be firmly closed. All vents shall be closed in a similar manner one after another in the direction of the flow except that at intermediate crests the vents immediately downstream shall be closed before their associated crest vent.

The injection tubes shall then be sealed off under pressure with a pressure of 0.5 N/mm^2 being maintained for at least one minute. Grout vents at high points shall be reopened immediately after 1 minute, while the grout is still fluid. Any escape of air, water or grout shall be recorded and reported immediately to the Overseeing Organisation. A further pumping of grout shall then be carried out to expel bleed water – and/or entrapped air. This shall be carried out with the vents open one at a time sequentially in the direction of grouting with a further 5 litres being released at each vent. In the event of disagreement over the quality of the vented grout, testing shall be undertaken immediately by the Contractor.

The injection tubes shall then be sealed off under pressure, with a pressure of 0.5 N/mm^2 being maintained for at least one minute.

The filled ducts shall not be subjected to shock or vibration for at least 24 hours from the time of grouting.

When the grout has set, the grout vents shall be temporarily reopened. If voids are apparent on inspecting vents at end caps, the Overseeing Organisation may require all or some of the end caps to be removed to demonstrate that they are satisfactorily filled with grout. End caps which have been removed shall then be replaced and permanently sealed against ingress of contaminants, such sealing to be proved to the Overseeing Organisation.

If the method of demonstrating filling of the anchorage caps involves their removal, a photographic record shall be made by the Contractor. The record shall clearly identify the individual anchorages, and shall be included in the report to the Overseeing Organisation.

If, in the opinion of the Overseeing Organisation, there is doubt that the ducts or any part of the system are not satisfactorily filled with grout, the Overseeing Organisation may require investigations to be carried out.

The Contractor shall keep full records of grouting for each duct in accordance with the certification scheme requirements for the installation of post-tensioning systems. Copies of these records shall be supplied to the Overseeing Organisation within 24 hours of completing grouting to each duct.

On completion of grouting, grout vents shall be positively sealed and waterproofed by a means separate from the concrete waterproofing.

Grouting During Cold Weather

7 (11/03) When the ambient temperature is expected to fall below 5°C, accurate records shall be kept by the Contractor of the maximum and minimum air temperatures, and the temperatures of the structural elements adjacent to the ducts to be grouted. No materials containing frost or ice shall be used, and the ducts and equipment shall be completely free of frost and ice.

Grout shall not be placed when the temperature of the structural elements adjacent to the ducts is below 4°C, or is likely to fall below 4°C during the following 48 hours, unless the element is heated so as to maintain the temperature of the placed grout above 5°C for at least 48 hours.

Methods of heating shall be to the acceptance of the Overseeing Organisation.

Ducts shall not be warmed with steam.

Properties of Grout

8 (05/02) The following criteria shall apply:

Fluidity

When tested by the method specified in sub-Clause 1711.9, the fluidity of the grout shall meet the criteria given in Table 17/14. Additionally, the fluidity (flow cone passage time) at outlets shall not vary from that of the injected grout by more than 20%.

TABLE 17/14: (11/03) **Test Requirements for Fluidity of Grout**

Test Method	Cone
Fluidity immediately after mixing	≤25 s (see note)
Fluidity at the end of the injection period subject to a minimum of 30 minutes after mixing*	≤25 s (see note)
Fluidity at duct outlet	≥10 s
* Mixing time shall be measured from the time when all of the materials are in the mixer. For pre-bagged grout the minimum time shall be 90 minutes.	
NOTE: For grouts prepared in some mixers which have a high shear mixing action, the upper limits given in Table 17/14 may be increased to 50 s. The mixer and these limits shall be subject to the acceptance of the Overseeing Organisation.	

Bleeding

When tested by the method referred to in sub-Clause 1711.9 the bleeding for grout shall be less than 1% of the initial volume of the grout and the average of 4 successive results shall be less than 0.3%. Testing shall be carried out at 24 hours.

Volume Change

The volume change assessed may be either an increase or decrease. When tested in accordance with the method referred to in sub-Clause 1711.9 the volume change of grout shall be within the range - 0% to + 5%.

Strength

The compressive strength of 100 mm cubes made of the grout shall exceed 27 N/mm^2 at 7 days. Cubes shall be made, cured and tested in accordance with BS EN 12390-1 and BS EN 123900-3.

Sieve Test

The grout shall contain no lumps. This shall be verified by testing as referred to in sub-Clause 1711.9.

Sedimentation Test

When tested by the method referred to in sub-Clause 1711.9 the grout shall not exhibit variation in density from top to bottom of a single test sample in excess of 5%.

Testing of Grout

9 (11/03) General. Suitability and acceptance tests for the properties of grout shall be determined in accordance with the Concrete Society Technical Report 47 “Durable Bonded Post-Tensioned Concrete Bridges” 2nd edition. The testing requirements are summarised in Table 17/15.

TABLE 17/15: (11/03) **Minimum Test Requirements for Grout**

Suitability Testing	
Fluidity	Sampled immediately after mixing, one test. After estimated time to grout duct or minimum of 90 mins from initial mixing. Two tests averaged in both cases.
Bleed Volume change Sedimentation Strength	Each sampled immediately after mixing, 3 tests averaged.
Acceptance Testing	
Fluidity	Sampled immediately after mixing, one test from mixer. After flow through duct, one test from each anchorage outlet. On completion, one test from the mixer.
Bleed Volume Change Strength	One tests per day or one per 1.5 m^3 of grout unless otherwise agreed by the Overseeing Organisation.
Sedimentation	One test per day for site bateched grout, or one test per pre-bagged supplied batch (by manufacturer’s reference number); subject to a minimum of one test per continuous grouting operation.

Admixtures

10 (11/03) The following criteria shall apply:

General

Admixtures shall be used where required to achieve a low water/cement ratio and impart good fluidity, minimum bleed and volume stability or expansion to the grout to comply with sub-Clause 1711.8. For site batched grout admixtures should be added on site during the mixing process and used in accordance with the manufacturer's recommendations. For pre-bagged grout the admixtures shall form a pre-blended component.

Types

Admixtures are divided into two types, expanding and non-expanding and they may be used to obtain the required grout performance. Admixtures used in combination shall be checked for compatibility by the Contractor, and reported to the Overseeing Organisation for acceptance.

Chemical Composition

Admixtures shall not contain substances in quantities that will adversely affect the grout or cause the grout to promote corrosion of the prestressing steel by rusting, pitting, stress corrosion or hydrogen embrittlement.

Material requirements

The admixture shall not segregate and shall be uniform in colour. The composition shall not change and the supplier shall operate a quality system complying with BS EN ISO 9001. The quality system shall be certified by a third party accredited by an appropriate organisation in accordance with sub-Clauses 105.3 and 105.4.

Where appropriate, admixtures shall comply with BS EN 934-4. Other admixtures shall be permitted provided they satisfy Clause 8 of BS EN 934-2 and full account is taken of their effects on the finished product and their fitness for purpose. Data on their suitability, including previous experience with such materials, shall be made available and records of the details and performance of such materials shall be maintained.

It should be noted that additional information beyond that required by Clause 8 of BS EN 934-2 must be provided by the manufacturer for admixtures bearing CE marking (see ZA.2.2 and ZA.3 of BS EN 934-2).

Dosage

The optimum dosage of any admixture shall be determined by trial mixes with the cement to be used in the grout. This dosage shall be expressed as percent by mass of the cement. It shall be within the range recommended by the supplier and shall not exceed 5% by mass of the cement. The method of measuring dosage and checking weights of pre-packed dry materials shall comply with sub-Clause 1711.5 or as otherwise agreed with the Overseeing Organisation.

1712 (05/01) Reinforcement - Materials

(05/02) **Hot Rolled and Cold Worked Carbon Steel Bars**

1 (05/02) All steel reinforcement specified shall comply with BS 4449 or BS 4483 and shall be cut and bent in compliance with BS 8666 and shall be obtained from a firm holding a valid CARES (or fully equivalent scheme) certificate of approval.

2 (05/02) Hot rolled and cold worked carbon steel bars shall comply with BS 4449 except that no bar shall contain a flash weld.

Hard Drawn Steel Wire

3 Hard drawn mild steel wire shall comply with BS 4482.

Steel Fabric

4 Steel fabric reinforcement shall comply with BS 4483 and shall be delivered to the Site in flat mats or pre-bent.

(05/02) **Stainless Steel Reinforcement**

5 (05/02) All stainless steel reinforcement shall comply with BS 6744 and shall be cut and bent in compliance with BS 8666 and shall be obtained from companies holding valid CARES (or fully equivalent scheme) certificares of approval for the production and supply of stainless reinforcement. Manufacturers who have applied for CARES regisration will be acceptable to the end of year 2002, subject to the approval of their quality manual and procedures by CARES.

6 (05/02) Stainless steel reinforcement shall be to the specified material strength grade in BS 6744.

Bond Strength

7 (05/02) The classification of deformed carbon steel bars as Type 1 or 2 for bond strength shall be in

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accordance with BS 4449. The type of deformed carbon steel bar shall be as described in Appendix 17/4.

Stainless steel reinforcement shall be plain or ribbed bar in accordance with BS 6744 and shall be as described in Appendix 17/4.

1713 (05/02) Carbon Steel Reinforcement and Stainless Steel Reinforcement - Bar Schedule Dimensions - Cutting and Bending

1 (05/02) The bar schedules are based on the dimensions of the concrete and the nominal cover to the reinforcement shown on the Drawings. The reinforcement shall be cut and bent within the tolerances given in BS 8666 but this shall not relieve the Contractor of his responsibility for the correct fit of the reinforcement and the achievement of the required cover as described in Clause 1714.

Bending of reinforcement at temperatures below 5°C or in excess of 100°C shall not be carried out.

Re-bending of grade 460 carbon steel bars on site shall not to be permitted. Re-bending of grade 250 bars not exceeding 12 mm may be carried out.

Re-bending of stainless steel reinforcement bars on site shall not be permitted.

Site storage of reinforcement should ensure that it is clear of the ground and covered with a waterproof sheeting or fixed cover, in order to reduce contamination and excess corrosion prior to placement.

1714 Reinforcement - Fixing

1 (05/02) Reinforcement shall be secured against displacement. Unless specified otherwise, the actual concrete cover shall be not less than the required nominal cover minus 5 mm.

The cover to a bar in an outer layer of reinforcement shall not exceed the nominal cover shown on the Drawings by more than 2% of the overall dimension of the member, measured in the same direction, or by more than 20 mm, whichever is the lesser. Bars in inner layers shall be located as shown on the Drawings; they shall be in close contact with the bars of the outer layer, unless otherwise indicated. Welding of carbon steel reinforcing bars for fixing purposes shall be in accordance with Clause 1717.

Welding of stainless steel reinforcement bars shall not be permitted.

Cover blocks shall be of comparable strength, durability and appearance to the surrounding concrete. They shall match the mix proportions of the adjacent material so far as is practicable. They shall ensure that the reinforcement is correctly positioned and shall be as small as possible consistent with their purpose, and designed so that they will not overturn or be displaced when the concrete is placed. Reinforcement spacers and chairs should be produced and fixed in accordance with the Concrete Society report CS 101.

Wire cast in the block for the purpose of tying it to the reinforcement shall be as described below.

Spacer blocks (categorised as heavy in the Concrete Society Report CS101) should be factory produced. Site produced concrete or mortar spacers shall not be used.

Projecting ends of ties or clips shall not encroach into the concrete cover. Tying wires shall be 1.2 mm diameter stainless steel wire throughout the structure excepting any locations as described in Appendix 17/4 where 1.6 mm soft annealed iron wire may be used. Stainless steel tying wire shall be used when tying stainless steel reinforcement.

The Contractor shall provide access and carry out a cover measurement survey of all reinforced concrete surfaces within the 24-hour period following the removal of formwork. The cover measurement survey shall be carried out on a 500 mm grid over the whole structure in general accordance with BA 35/90.

1715 Reinforcement - Surface Condition

1 (05/01) Immediately before concrete is placed around it, reinforcement shall be free from mud, oil, paint, retarder, release agent, loose rust, loose mill scale, snow, ice, grease or any other substance that can be shown to have an adverse chemical effect on the steel or concrete, or to reduce the bond between the steel and the concrete.

1716 (05/01) Reinforcement - Laps and Joints

1 Laps and joints shall be made only where shown on the Drawings, except in the case where additional laps or splice bars are required and the Overseeing Organisation's approval has been obtained.

2 Where reinforcing bars are required to be coupled the coupling system shall have a current British Board of Agrément Roads and Bridges Certificate or CARES Certificate of Product Assessment and shall be sourced from a firm holding relevant valid CARES (or fully equivalent scheme) certificate of approval. Couplers shall comply with cover requirements of sub-Clause 1714.1.

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1717 Reinforcement - Welding

General

1 (05/02) Welded reinforcement, other than steel fabric reinforcement, shall not be incorporated in the Permanent Works unless permitted in Appendix 17/4. When required, the Contractor shall demonstrate that at each location the fatigue life, durability and other properties of the member are not adversely affected by the proposal.

Site welding of stainless steel reinforcement bars shall not be permitted.

(05/02) Flash Butt Welding for Carbon Steel

2 (05/01) Flash butt welding shall only be carried out with an appropriate combination of flashing, heating, upsetting and annealing and subject to the demonstration of the satisfactory performance of trial joints. Only those machines that automatically control this cycle of operations shall be used.

(05/02) Manual Metal-arc Welding for Carbon Steel

3 (05/01) Metal-arc welding shall be carried out in accordance with BS 7123 and the recommendations of the reinforcement manufacturer, subject to the demonstration of the satisfactory performance of trial joints.

(05/02) Other Methods of Welding for Carbon Steel

4 (05/01) Other methods of welding may be used subject to the demonstration of the satisfactory performance of trial joints.

Strength of Structural Welded Joints

5 (05/02) The strength of all structural welded joints shall be assessed following tests on trial joints to establish the minimum specified mechanical properties of the joint. Tests shall be carried out by an independent testing body as specified in BS 8666.

1718 Prestressing Tendons - Materials

Steel Wire

1 (05/01) Steel wire shall comply with BS 5896.

Cold Worked High Tensile Alloy Bar

2 Cold worked high tensile alloy steel bars for prestressed concrete shall comply with BS 4486.

Stress-relieved Seven-wire Strand

3 (05/01) Stress-relieved seven-wire strand shall comply with BS 5896 or have properties that are not inferior.

Sampling and Testing

4 (05/01) When it is proposed to use super strand complying with BS 5896 : Table 6, or other than the lowest strength 3, 4, 5, 6 or 7 mm diameter wires complying with BS 5896 Tables 4 or 5 the following shall apply:

(i) A sample shall be taken from each reel of material proposed for use in the Works.

(ii) A reel shall only be accepted if both the breaking load and the 0.1% proof load of the sample exceeds the specified characteristic loads given in Tables 4 or 6. In the case of Table 5 this requirement shall apply to the breaking load and the load at 1% elongation.

5 (11/03) Where scheduled in Appendix 1/5, the Contractor shall arrange for samples of the steel intended for use in the Works to be tested at a testing laboratory appropriately accredited by an appropriate organisation in accordance with sub-Clauses 105.3 and 105.4.

1719 Prestressing Tendons - Handling and Storage

1 Care shall be taken to avoid mechanically damaging, work-hardening or heating prestressing tendons while handling. All prestressing tendons shall be stored clear of the ground and protected from the weather, from splashes from any other materials, and from splashes from the cutting operation of an oxy-acetylene torch, or arc-welding processes in the vicinity.

In no circumstances shall prestressing tendons after manufacture be subjected to any welding operation, or heat treatment or metallic coating such as galvanizing. This does not preclude cutting as described in Clause 1722.

1720 Prestressing Tendons - Surface Condition

1 (05/01) Prestressing tendons and internal and external surfaces of sheaths or ducts shall be clean and free from pitting at the time of incorporation in the work. Slight surface rusting is acceptable.

1721 Prestressing Tendons - Straightness

Wire

1 Low relaxation and normal relaxation wire shall be in coils of sufficiently large diameter to ensure that the wire pays off straight, except that in cases where straight as-drawn wire is not essential, wire in small-diameter coils (corresponding to the diameter of the blocks in the drawing machine) may be used.

Strand

2 Prestressing strand, however manufactured, shall be in coils of sufficiently large diameter to ensure that the strand pays off straight.

Bars

3 (05/01) Prestressing bars as delivered shall be straight. Any small adjustments for straightness that are necessary on Site shall be made by hand. Bars bent in the threaded portion shall be rejected. Any straightening of bars shall be carried out cold but at a temperature of not less than 5°C. Any necessary warming shall be by means of steam or hot water.

1722 Prestressing Tendons - Cutting

1 All cutting of wire, strand or bar shall be carried out using either:

(i) a high-speed abrasive cutting wheel, friction saw or equivalent mechanical method at not less than one diameter from the anchor; or

(ii) an oxy-acetylene cutting flame, using excess oxygen to ensure a cutting rather than a melting action, not less than 75 mm from the anchor. The temperature of the tendon adjacent to the anchor shall not be greater than 200°C. Care shall be taken that neither the flame nor splashes come into contact with the anchorages or tendons.

1723 Prestressing Tendons - Positioning of Tendons, Sheaths and Duct Formers

1 Tendons, sheaths and duct formers shall be accurately located and maintained in position both vertically and horizontally as shown on the Drawings. Unless otherwise described in Appendix 17/4 the tolerance in the location of the centre line of sheath or duct shall be ± 5 mm.

Where tendons are described in the Contract as debonded from the concrete they shall be covered with suitable sleeves. The ends of the sleeves shall be taped to the tendon to prevent the ingress of grout.

Joints in sheaths shall be securely taped to prevent penetration of the duct by concrete or laitance, and ends of ducts shall be sealed and protected after the stressing and grouting operations. Joints in adjacent sheaths shall be spaced at least 300 mm apart.

1724 Prestressing Tendons - Tensioning

General

1 All wires, strands or bars stressed in one operation shall be taken, where possible, from the same parcel. Each cable shall be tagged with its number from which the coil numbers of the steel used can be identified. Cables shall not be kinked or twisted. Individual wires and strands for which extensions are to be measured shall be readily identifiable at each end of the member. No strand that has become unravelled shall be used.

Tensioning Apparatus

2 The tensioning apparatus shall meet the following general requirements:

(i) The means of attachment of the tendon to the jack or tensioning device shall be safe and secure.

(ii) Where two or more wires or strands are stressed simultaneously, they shall be approximately of equal length between anchorage points at the datum of load and extension measurement. The degree of variation shall be small compared with the expected extension.

(iii) The tensioning apparatus shall be such that a controlled total force is imposed gradually and no dangerous secondary stresses are induced in the tendons, anchorage or concrete.

(iv) The force in the tendons during tensioning shall be measured by direct-reading load cells or obtained indirectly from gauges fitted in the hydraulic system to determine the pressure in the jacks. Facilities shall be provided for the measurement of the extension of the tendon and of any movement of the tendon in the gripping devices. The load measuring device shall be calibrated to an accuracy within ± 2% and checked at frequent intervals.

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Elongation of the tendon shall be measured to an accuracy within 2% or 2 mm, whichever is the lesser.

(v) The tensioning equipment shall be calibrated before the tensioning operation and subsequently at frequent intervals.

Pretensioning

3 Where pretensioning methods are used, the tension shall be fully maintained by some positive means during the period between tensioning and transfer. The transfer of stress shall take place slowly to minimize shock.

(i) Straight tendons. In the long-line method of pretensioning, sufficient locator plates shall be distributed throughout the length of the bed to ensure that the wires or strands are maintained in their proper position during concreting. Where a number of units are made in line, they shall be free to slide in the direction of their length and thus permit transfer of the prestressing force to the concrete along the whole line.

In the individual mould system, the moulds shall be sufficiently rigid to provide the reaction to the prestressing force without distortion.

(ii) Deflected tendons. Where possible, the mechanisms for holding down or holding up tendons shall ensure that the part in contact with the tendon is free to move in the line of the tendon so that frictional losses are nullified. If, however, a system is used that develops a frictional force, this force shall be determined by test and due allowance made.

For single tendons the deflector in contact with the tendon shall have a radius of not less than 5 times the tendon diameter for wire or 10 times the tendon diameter for strand, and the total angle of deflection shall not exceed 15°.

The transfer of the prestressing force to the concrete shall be effected in conjunction with the release of hold-down and hold-up forces.

Unless otherwise described in Appendix 17/4, concrete shall not be stressed until it has reached at least the age at which 2 test cubes taken from it attain the specified transfer strength. The test cubes shall be made and tested as described in BS 1881 : Part 108 and BS 1881 : Part 116 respectively. They shall be cured in similar conditions to the concrete to which they relate. The Contractor shall cast and test sufficient cubes to demonstrate that the required strength of the concrete at transfer has been reached.

Post-tensioning

4 (i) (05/01) Arrangement of tendons. Where wires, strands or bars in a tendon are not stressed simultaneously, the use of spacers shall be in accordance with the recommendations of the system manufacturer.

(ii) Anchorages. Anchorages shall be tested in accordance with BS 4447.

For each anchorage system used in the Works, the characteristic value for anchorage efficiency shall be not less than 90%.

Proprietary anchorages shall be handled and used strictly in accordance with the manufacturer's instructions and recommendations.

(iii) Deflected tendons. The deflector in contact with the tendon shall have a radius of not less than 50 times the diameter of the tendon, and the total angle of deflection shall not exceed 15°.

(iv) Tensioning procedure. Before tensioning, the Contractor shall demonstrate that all tendons are free to move in the ducts unless the geometry of the ducts makes this impracticable. Tensioning shall be carried out in such a manner that the stress in the tendons increases at a gradual and steady rate. Tensioning shall not be carried out at a temperature below 0°C.

Unless otherwise described in Appendix 17/4, concrete shall not be stressed until it has reached at least the age at which 2 test cubes taken from it attain the specified transfer strength. The test cubes shall be made and tested as described in BS 1881 : Part 108 and BS 1881 : Part 116 respectively. They shall be cured in similar conditions to the concrete to which they relate. The Contractor shall cast and test sufficient cubes to demonstrate that the required strength of the concrete at transfer has been reached.

The Contractor shall ensure that those carrying out the stressing are provided with

particulars of the required tendon loads, order of stressing and extensions. Allowance shall be made during stressing for the friction in the jack and in the anchorage, although the former is not necessary when using load cells, and for draw-in of the tendon during anchoring.

Stressing shall continue until the required extension and tendon load are reached.

The extension shall allow for any draw-in of the tendon occurring at a non-jacking end, but measurement shall not commence until any slack in the tendon has been taken up.

Immediately after anchoring, the forces in the prestressing tendons shall not exceed 70% of their characteristic strength. During stressing the value may exceed 70% of their characteristic strength but shall not exceed 80%.

After the tendons have been anchored, the force exerted by the tensioning apparatus shall be decreased gradually and steadily so as to avoid shock to the tendon or the anchorage. Full records shall be kept of all tensioning operations, including the measured extensions, pressure-gauge or load-cell readings, and the amount of draw-in at each anchorage. When requested copies of these records shall be provided within 24 hours of each tensioning operation.

Tendons shall not be cut within 3 days of their being grouted.

1725 Prestressing Tendons - Protection and Bond

1 The prestressing tendons shall be protected in their permanent positions from both mechanical damage and corrosion as described in Appendix 17/4.

1726 Stainless Steel Dowels - Materials

1 (05/02) Dowels shall be made from Steel Designation 1.4429 or 1.4436 and Grade 200 or 500 steel bars complying with BS 6744.

1727 Inspection and Testing of Structures and Components

General

1 Inspection and testing of structures and components shall be carried out as described in Appendix 17/4.