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Specification for Road Works Series 1700 - Structural Concrete

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Standards

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Amendment Details:

This Standard supersedes the December 2013 version of CC-SPW-01700. The principle changes from the previous version are as follows:

a) References have been updated from NRA to TII and document references have been updated to TII Publications numbers.

b) Additional information in relation to the specification for ggbs has been included in 1702 Concrete – Constituent Materials.

c) A requirement for individuals working on the production of concrete for national road schemes to be in possession of an Irish Concrete Society 'Concrete Ticket' card or equivalent has been included in 1706 Concrete – Production.

d) 1707 Concrete – Conformity and Identity Testing has been corrected to clarify that Identity testing shall be as scheduled in Appendix 1/5.

e) A requirement for individuals working on the execution of concrete for national road schemes to be in possession of an Irish Concrete Society 'Concrete Ticket' card or equivalent has been included in 1710 Concrete – Construction Control.

STRUCTURAL CONCRETE

Contents

Structural Concrete

1701 Concrete - General

1 Concrete shall conform to the requirements of I.S. EN 206-1 and DN-STR-03012. Concrete shall be specified as designed concrete. Details of the structural concrete in the Works are given in Appendix 17/1.

Designed Concrete

2 The specification for designed concrete shall contain:

(a) the basic requirements given in 6.2.2 of I.S. EN 206-1;

(b) the additional requirements given in 6.2.3 of I.S. EN 206-1.

Implementation of I.S. EN 13670

3 The execution of concrete structures shall be in accordance with I.S. EN 13670 as complemented by this Specification. The provisions of this Specification apply to both in situ and precast concrete, unless noted otherwise.

The contractor shall ensure that before commencement of execution of any part of the work, the execution specification relevant to that part of the works is complete and available. The contractor shall update the execution specification to reflect any changes made during the project.

Execution Class

4 The works are to be built in accordance with Execution Class 3 as defined in I.S. EN 13670, unless otherwise specified in Appendix 17/4.

Inspection Requirements

5 Inspection for materials and products and inspection for execution of works, as well as documentation of inspection, shall be in accordance with I.S. EN 13670 as complemented by this Specification. Requirements for the inspection and testing of structures are given in Appendix 17/4. If parts of the structure are designated as Inspection Level 3 in accordance with I.S. EN 1990 and therefore require third party inspection by an organisation different from that which executed the Works, they shall be fully described in Appendix 17/4. Specification clauses may include other inspection requirements.

1702 Concrete – Constituent Materials

Cement

1 (i) Unless an alternative has been agreed with the Structures Section of Transport Infrastructure Ireland (TII) and included in Appendix 17/4, cement types as defined in Irish National Annex to I.S. EN 206-1 (Tables NA 2 and NA 3) shall comprise one of the following:

(a) CEM I,

(b) CEM II/A-L,

(c) CEM II/A-LL,

(d) CEM II/A-S,

(e) CEM II/B-S,

(f) CEM II/A-V,

(g) CEM III/A,

(h) SRPC.

(ii) Combinations with a Type II addition (see Irish National Annex to I.S. EN 206-1 Clause NA 2.4 and NA 2.7) shall comprise one of the following:

(a) CEM I cement conforming to I.S. EN 197-1 with addition of ground granulated blastfurnace slag (ggbs) conforming to I.S. EN 15167-1 up to a maximum of 70% by weight (expressed as ggbs/(cement+ggbs)) provided that equivalent strength performance is demonstrated to at least a class 42,5N cement;

(b) CEM II/A-L(LL) or CEM II/A-V cement conforming to I.S. EN 197-1 with addition of ggbs conforming to I.S. EN 15167-1 up to a maximum of 50% by weight (expressed as ggbs/(cement+ggbs)) provided that equivalent strength performance is demonstrated to at least a class 42,5N cement;

(c) CEM I, CEM II/A-L(LL) or CEM II/A-V cement conforming to I.S. EN 197-1 with addition of Fly Ash conforming to I.S. EN 450-1 in accordance with the requirements of Clause NA 2.7 of the Irish National Annex to I.S. EN 206-1.

(iii) Ground granulated blastfurnace slag (ggbs), used as a clinker substitute in the cement combination, shall:

(a) comply with the requirements of I.S. EN 15167 and carry a CE mark.

(b) have a particle size Blaine value ≥ 420 m²/kg.

(c) be supplied with a Declaration of Performance confirming a CaO content of $\geq 40\%$ and a Al2O3 content of $\leq 14\%$.

(d) be supplied with a third party verified Type III Environmental Product Declaration conforming to I.S. EN 15804.
(e) be supplied by an organisation who hold current ISO 9001 and ISO 14001 certification.

The use of high alumina cement concrete is not permitted.

Aggregates

2 Aggregates shall conform to I.S. EN 12620 (for normal and heavy-weight aggregates) and to I.S. EN 13055-1 (for light weight aggregates) 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 I.S. EN 933-3 shall not exceed FI35 except when natural, uncrushed aggregates are used for concrete of strength classes lower than C32/40, when the flakiness index shall not exceed FI50. No flakiness index limit is required for strength class C12/15 concrete or below.

The resistance to fragmentation of the coarse aggregate, determined in terms of the Los Angeles coefficient as specified in I.S. EN 1097-2 and declared in accordance with the relevant category specified in Table 12 of I.S. EN 12620, shall meet the requirements for LA40.

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 I.S. EN 1744-1, or less frequently when the long term variability has been established.

The level of attestation of aggregates shall be 2+ in accordance with Table ZA.2a) of I.S. EN 12620 for all structural concrete Grade 32/40 and above.

Admixtures and Pigments

3 Admixtures shall conform to I.S. EN 934-2.

Where a specified coloured concrete requires a pigment, the pigment shall conform to I.S EN 12878.

In all cases the Contractor shall record the following information:

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

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

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

Fibres in Concrete

4 The use of fibres for concrete is not covered by this Specification. Where the use of steel and polymer fibres conforming to I.S. EN 14889 as a reinforcement for concrete is considered appropriate, its specification would require submission and approval through the Employer's Departures processes.

Water

5 Water used in the production of concrete shall conform to I.S. EN 1008.

1703 Concrete – Exposure Classes

Exposure Classes

1 Concrete mixes shall be designed to meet the requirements of I.S. EN 206-1 and DN-STR-03012 for the exposure classes defined in Appendix 17/1.

1704 Concrete – General Requirements

Compressive Strength Class of Concrete

1 Compressive strength of concrete shall be as described in Appendix 17/1.

Minimum Cement Content and Maximum Water/Cement Ratio

2 The cement content shall be not less than, and the water/cement ratio shall be not greater than that defined in DN-STR-03012.

Maximum Cement Content

3 The cement content shall not exceed 550 kg/m^3 unless otherwise described in Appendix 17/1.

Maximum Chloride Content

4 The chloride content class shall conform to the requirements of Table 17/1.

Control of Alkali-Silica Reaction

5 The Contractor shall submit evidence of compliance with one of the following procedures (i) – (iii) below.

(i) For protection of the structure by controlling the reactive silica content of the aggregates, the following shall be complied with:

(a) Representative samples of the aggregates to be used shall be subjected to petrographic examination by a competent petrographer whose CV shall be submitted to the Employer's Representative. The definition of rock types shall be as per I.S. EN 932-3. Where the geological formation of the source material is complex, data from borings shall be submitted to prove the nature of the parent strata.

(b) The petrographer shall produce a report and shall quantify the presence if any of the potentially reactive constituents listed in Table 17/2. The report shall state the geological age of any chert discovered. Where the petrographer is evaluating a parent rock or gravel the report shall indicate the percentage of such constituents likely to remain in the aggregates after they have been processed to I.S. EN 12620.

(c) The Contractor shall then submit the Petrographer's report together with a report showing the percentage of the potentially reactive constituents which will occur in the proposed concrete mix as a result of blending the coarse and fine aggregates.

(d) If the content of potentially reactive minerals or rock is above the limits given in the second column in Table 17/2, the aggregates may only be incorporated in the Works at the absolute discretion of the Employer's Representative following further assessment as per sub-clause (i)(b).

(e) Where the limits of potentially reactive material given in Table 17/2 are exceeded, the aggregates may still be acceptable at the Employer's Representative's sole discretion. To enable the Employer's Representative to

determine acceptability or otherwise of the aggregates, the Contractor shall carry out testing in accordance with ASTM C-289 and ASTM C-227 or as may be otherwise directed.

(ii) For protection of the structure by controlling the alkali content of the cement, the alkali content of the Portland cement shall not exceed 0.6%. The alkali content of the Portland cement shall be taken as the certified average acid soluble alkali content of the cement plus 1.64 times the standard deviation. The certified average acid soluble alkali content shall be the average of the last 25 determinations of alkali content carried out on consecutive daily samples immediately prior to submission. The Contractor shall submit the test certificates furnished by the cement manufacturer. The alkali content of the Portland cement shall be determined in accordance with I.S. EN 196-2.

(iii) For protection of the structure by controlling the alkali content of the concrete, the calculated alkali content of the concrete mix shall not exceed the maximum alkali load as defined in Table 17/3.

(a) The alkali content of the Portland Cement shall be determined in accordance with Clause 1704.5 (ii).

(b) The Contractor shall submit test certificates giving the acid soluble alkali content of any slag or pulverised fuel ash to be used. These shall be determined using an approved method based on I.S. EN 196-2.

(c) The equivalent sodium chloride content of the coarse and fine aggregate shall be calculated from the quantity of chloride ion present, which shall be measured by the method in I.S. EN 1744-1.

(d) The calculated alkali content of the concrete mix shall be determined by summing the alkali load value contributed by each of the constituents of the concrete in accordance with Table 17/4. The Contractor shall submit a report detailing the assessed alkali content of the concrete mix.

TABLE 17/1: 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 sulphate resisting Portland cement conforming to I.S. EN 197-1	Cl 0,20	0.20%
Concrete containing embedded metal and made with other permitted cements	Cl 0,30	0.30%
Not containing steel reinforcement or other embedded metal with the exception of corrosion-resisting lifting devices	Cl 1,0	1.0%

TABLE 17/2: Aggregate Types

Potentially reactive mineral or rock	Acceptable Maximum Content
Opaline silica Cristobalite Tridymite	Zero
Microcrystalline and cryptocrystalline quartz Chalcedony, flint and chert(1) Volcanic Glass	5%

Note(1)

Aggregates used in concrete in the Republic of Ireland have significant amounts of chert containing chalcedony and microcrystalline quartz. The majority of these cherts are of Carboniferous age and have undergone deformations and low grade metamorphism. This has stabilised their crystal structure and they have a low potential reactivity compared with geologically younger materials. Cherts from the Cretaceous era have been found in Northern Ireland and on the east coast of Ireland. These younger materials have a different geological history to the Carboniferous cherts, have a less crystalline structure and might be significant if used in circumstances potentially susceptible to ASR.

TABLE 17/3: Alkali Load Limitation Values

Aggregate	Maximum Alkali Load
Aggregate other than greywacke	4.5 Na_2O_{eq} kg/m^3
Greywacke aggregate	3.5 Na_2O_{eq} kg/m^3

TABLE 17/4: Summation of Alkali Load Value

Contributor	Contribution	Determination
Cement	Certified average alkali content plus an allowance for variability of 1.64 standard deviations, factored by cement content	Cement content x (Average Na_2O_{eq} + 1.64 standard deviations) $Na_2O_{eq} = Na_2O_{eq} + 0.658\ K_2O$
Ground granulated blastfurnace slag	If ggbs content is less than 40%: One hundred per cent of acid soluble alkali content plus an allowance for variability of 1.64 standard deviations, factored by ggbs content.	ggbs content x (Average Na_2O_{eq} + 1.64 standard deviations) if ggbs content < 40%
	If ggbs content is equal to or greater than 40%: Fifty per cent of acid soluble alkali content plus an allowance for variability of 1.64 standard deviations, factored by ggbs content.	ggbs content x 0.5 (Average Na_2O_{eq} + 1.64 standard deviations) if ggbs content $\geq$ 40%
Pulverised fuel ash	If pfa content is less than 21%: One hundred per cent of acid soluble alkali content plus an allowance for variability of 1.64 standard deviations, factored by pfa content.	pfa content x (Average Na_2O_{eq} + 1.64 standard deviations) if pfa content < 21%
	If pfa content is equal to or greater than 21%: Twenty per cent of acid soluble alkali content plus an allowance for variability of 1.64 standard deviations, factored by pfa content.	pfa content x 0.2 (Average Na_2O_{eq} + 1.64 standard deviations) if pfa content $\geq$21%
Aggregates	Chloride ion content, expressed as a percentage by mass, factored by 0.76. May be ignored if the chloride ion is less than 0.02%.	0.76 x (Cl^- content) unless Cl^- < 0.02%
Admixture	Alkali content of admixture, if any, factored to take account of dosage rate.	(Na_2O_{eq}) x dosage rate factor
Water	Chloride ion content, expressed as a percentage by mass, factored by 0.76. May be ignored if the chloride ion content is less than 0.02%.	0.76 x (Cl^- content) unless Cl^- < 0.02%

Buried Concrete Exposed to Sulfates

6 Choice of concrete and additional protective measures where concrete is exposed to sulfates shall comply with I.S. EN 206-1.

Early Thermal Cracking

7 The execution of concrete structures shall conform to the assumptions made in the design to control early thermal cracking and described in Appendix 17/1, unless otherwise agreed with the Employer's Representative.

1705 Concrete – Requirements for Designed Concrete

Conformity Criteria

1 The conformity criteria for a concrete shall be in accordance with I.S. EN 206-1 and DN-STR-03012.

Suitability of Proposed Constituent Material Proportions

2 Prior to the supply of any designed concrete, the Contractor shall provide the following information to the Employer's Representative:

(i) the nature and source of each material;

(ii) either:
  (a) appropriate existing data as evidence of satisfactory previous performance for: target mean strength, current margin, consistence and water/cement ratio; or
  (b) full details of initial tests carried out in accordance with Annex A of I.S. EN 206-1.

(iii) 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

Production Control

1 All concrete shall be subject to production control under the responsibility of the producer, as specified in Clause 9 of I.S. EN 206-1.

Production, including but not limited to batching and delivery, shall be carried out by suitably qualified personnel. Qualification may be demonstrated, in part, by holding a current Irish Concrete Society 'Concrete Ticket' card or equivalent. All individuals working on the production of concrete for national road schemes must be in possession of this card or equivalent at a minimum.

Consistence at Delivery

2 Water or admixtures shall not be added to delivered concrete.

Self-Compacting Concrete (SCC)

3 SCC shall not be used for insitu works and shall only be used in the production of factory produced precast elements and only where prior approval has been granted by the Employer's Representative.

Where approval is granted for factory produced precast elements, SCC shall conform to the requirements of I.S. EN 206-9 and testing shall be conducted in accordance with I.S. EN 12350-8 to 12.

1707 Concrete – Conformity and Identity Testing

General

1 Sampling and testing of fresh and of hardened concrete shall comply with I.S. EN 206-1 and as described in Appendix 17/4 and shall be as scheduled in Appendices 1/5 and/or 1/6 as appropriate, in accordance with Clauses 105 and 106.

Identity Testing

2 Where identity testing is required, as described in Appendix 17/4, it shall be in accordance with the requirements given in Annex B of I.S. 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. Identity testing shall be as scheduled in Appendix 1/5.

1708 Concrete – Surface Finish

Trial Panels

1 Before commencing concreting of any exposed concrete, 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.

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 (i.e. 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 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) Formed Surfaces – Classes of Finish

Formwork as described in sub-Clause 1710.2 shall be of sufficient quality so as to be capable without the need for remedial works of producing the following finishes where required in the Works;

a) **Class F1**. No extra requirement.

b) **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.

c) **Class F3**. The resulting finish, immediately upon removal of the formwork, 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. Internal ties and embedded metal parts shall not be used. The Contractor shall submit a survey of the as struck finish identifying any minor imperfections prior to any making good, together with a method statement for any proposed remedial works.

d) **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.

e) **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 Works on a regular spacing, shall be allowed.

f) **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.

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

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

b) **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.

c) **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.

d) **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 10mm over a 3m gauge length or have any abrupt irregularities more than 3mm.

e) **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 5mm over a 3m gauge length or have any abrupt irregularities.

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

1709 Concrete – Surface Protection Systems

General

1 (i) Surface protection systems shall be applied to those surfaces described within the Contract and Appendix 17/2 in accordance with the manufacturer's instructions taking particular note of the relevant Health and Safety and waste disposal requirements.

Material

2 (i) The surface protection system shall be an impregnant that achieves I.S. EN 1504-2 values for hydrophobic impregnation of concrete.

(ii) The Contractor shall submit with each delivery a certificate that the material in that delivery complies with sub-Clause 2(i) of this Clause.

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

(iv) The containers shall remain sealed until their contents are required for use. Any part used containers are to be kept tightly closed at all times when not in use. The contents of any opened container shall be used within 48 hours or else disposed of safely in accordance with Clause 7 of this Clause.

(v) The assessment of the durability of an impregnating material will be based on the submission 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 impregnant 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 impregnant material 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 vehicular traffic by providing suitable and adequate protection and traffic management. The Contractor shall submit details of the proposed protection measures and shall obtain all other consents 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 Employer's Representative 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. Immediately prior to application, the surface of the concrete shall be cleaned with dry compressed air through a lance to remove any loose material and dust. A water trap shall be incorporated in the air line.

(iii) Water jetting or steam cleaning shall not in general be used as a means of surface preparation without agreement with the Employer's Representative.

Application

6 (i) The Contractor shall submit a method statement 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) Impregnation shall be carried out not less than 7 days after the concrete has been placed, and 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. The material shall be applied in accordance with the manufacturer's recommendations such that the dosage rate exceeds the amount found necessary to meet the requirements of I.S. EN 1504-2 for hydrophobic testing criteria.

(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 relevant Local 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 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 including rate of application.

1710 Concrete – Construction General

Construction Joints

1 The position of construction joints shall be as shown on the drawings in the Contract 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.

Unless interface shear calculations in accordance with I.S. EN 1992-2 (Clause 6.2.5 of I.S. EN 1992-1-1) show that a non-prepared surface between concrete cast at different times is sufficient for structural purposes, 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 stainless steel open-mesh permanent formwork intended for use in construction joints in accordance with the manufacturer's recommendations.

Any proposed use of a construction joint with a non-prepared surface between concrete cast at different times shall require preapproval from the Structures Section of TII. Their use must be noted within the Technical Acceptance Report as required by DN-STR-03001.

Retarding agents shall not be used.

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

Falsework and Formwork

2 (i) 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 in 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 are required 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 jointing faces of the pocket shall be prepared with an exposed aggregate finish 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 sources of any compressed air used for the cleaning 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 or special formwork shall comply with Appendix 17/4.

(v) Control. The design, detailing, construction and use of temporary works is the sole responsibility of the Contractor. All design and detailing of temporary works shall be carried out under the control of a competent temporary works designer and construction and use shall be under the direct control of a competent falsework coordinator.

Transporting, Placing and Compacting

3 The execution of concrete works on site, including but not limited to receiving, conveying, placing, compacting, finishing and curing, shall be carried out by suitably qualified personnel. Qualification may be demonstrated, in part, by holding a current Irish Concrete Society 'Concrete Ticket' card or equivalent. All individuals working on the execution of concrete works on national road schemes must be in possession of this card or equivalent at a minimum.

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 $5^{O}C$ and not more than $30^{O}C$. 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.

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. 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.

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.

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 subject to the approval of the Employer's Representative. 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.

Slip forming shall be performed in accordance with Clause 8.4.5 of I.S. EN 13670 and shall comply with Appendix 17/4.

Removal of Falsework and Formwork

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

(ii) Timing of removal for cast insitu concrete. When 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 removed when the cylinder/cube strength is C12/15N/mm^2 or the strength needed by the design with an allowance for material safety factors and deviation in testing results, 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 17/5.

TABLE 17/5: Minimum Period Before Removing Falsework and Formwork (CEM I or SRPC Concrete)

	Minimum Period Before Removal		
	Surface Temperature of Concrete		
	16^{O}C	**7^{O}C**	**t^{O}C (any temperature between 0^{O}C and 25^{O}C)**
Vertical formwork to columns, walls and large beams	12 hours	18 hours	300/(t + 10) hours
Soffit formwork to slabs	4 days	6 days	100/(t + 10) days
Props to slabs	10 days	15 days	250/(t + 10) days
Soffit formwork to Beams	9 days	14 days	230/(t + 10) days
Props to Beams	14 days	21 days	360/(t + 10) days

Where surface temperatures of concrete fall outside or are likely to fall outside the above temperature ranges, agreement shall be reached between the Contractor and Employer's Representative on appropriate removal times.

Curing of Concrete

5 (i) Curing methods. Curing Class 3 in accordance with Clause 8.5 of I.S. EN 13670 shall be used unless otherwise specified in Appendix 17/4. Additional special curing requirements may be given in Appendix 17/4.

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.

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. The Contractor shall keep records of all curing liquid, compounds and membranes and their subsequent removal from the areas scheduled in Appendix 17/2.

(ii) 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^{O}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^{O}C per ½ hour.

c) The concrete temperature shall at no time exceed 70^{O}C.

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

e) Testing samples 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 permitted.

Cold Weather Work

6 When concrete is placed at air temperatures below $2^{O}C$, 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 $5^{O}C$ and shall not exceed $30^{O}C$.

(iii) The surface temperature of the concrete shall be maintained at not less than $5^{O}C$ until the concrete reaches a strength of $C4/5N/mm^2$ as determined by tests on samples that were cured under identical conditions on 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 $60^{O}C$.

Hot Weather Work

7 During hot weather the Contractor shall ensure that constituent materials of the concrete are sufficiently cool to prevent the concrete from stiffening in the interval between it's 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 $60^{O}C$.

Precast Concrete Construction

8 (i) General. Factory produced or site manufactured precast concrete elements are defined by I.S. EN 13670 as 'precast products' if they are manufactured and designed in accordance with a relevant European Product Standard or with I.S. EN 13369 'Common rules for precast concrete products'. Where precast products are manufactured in temporary plants on site, the production shall be protected against adverse weather conditions and production control shall satisfy the requirements of Clause 6 of I.S. EN 13369.

All precast elements to be used in the Works that fall within the scope of a relevant European Product Standard, shall be supplied in accordance with that Standard. Precast elements that are outside the scope of a European Product Standard shall normally conform to I.S. EN 13369. Although I.S. EN 13670 recognises the possibility of use of precast concrete elements not conforming to any European Product Standard or I.S. EN 13369, which therefore cannot be considered as precast products, this is expected to be uncommon and confined to minor site manufactured precast elements; in such cases, manufacture and construction operations shall comply with the provisions of I.S. EN 13670 and with this Specification.

For precast products, the manufacturing requirements are covered in their relevant European Product Standard or in I.S. EN 13369; the construction operations from the reception at the site or, if site manufactured, from removal from the forms, shall comply with the provisions of I.S. EN 13670 and with this Specification.

The allowable dimensional tolerance of precast elements shall be in accordance with Clause 1728.

(ii) Manufacture of precast products. Precast products shall be suitable for their intended use and place of installation in the Works. The relevant European Product Standard for each precast product to be used shall be identified in Appendix 17/7. Where there is no relevant European Product Standard, reference to manufacture in accordance with I.S. EN 13369 shall be quoted in Appendix 17/7.

The requirement and method of CE marking, as defined in Annex ZA of the relevant European Product Standard, shall be defined in Appendix 17/7.

(iii) Manufacture of precast concrete elements not conforming to any European Product Standard or to I.S. EN 13369. The Contractor shall give reasonable notice to the Employer's Representative in advance of the date of commencement of manufacture and casting of each type of element.

A copy of all 28-day test results relating to the work as scheduled in Appendix 1/5, shall be made available to the Employer's Representative in accordance with clause 105.

For all prestressed elements, 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 cylinders/ cubes cast as described in sub-Clause 1724.3(ii) and 1724.4(iv) and the minimum age in hours of the concrete at the time the stress was applied to the element.

For all prestressed pretensioned elements the length, cross-section dimensions and straightness of precast concrete shall be measured at 28 $\pm$ 2 days after casting. If earlier measurement is required, the manufacturer should allow for further shrinkage and creep between the time of measurement and 28 days, based on recorded experience.

All elements shall be indelibly marked to show the element mark as shown on the drawings in the Contract, the production line on which the concrete was cast, the weight of the element, the date on which the concrete was cast and, if they are of symmetrical section, the face that will be uppermost when the element is in its correct position in the Works. The markings shall be so located that they are not exposed to view when the element is in its permanent position.

(iv) Requirements for all precast elements (including precast products)

a) General. Where tests are to be carried out, no elements to which the tests relate shall be dispatched to the site until the tests have been satisfactorily completed. In the case where elements are manufactured in temporary plants on site, they shall not leave the designated production area until the tests have been satisfactorily completed.

Unless interface shear calculations in accordance with I.S. EN 1992-2 (Clause 6.2.5 of I.S. EN 1992-1-1) show that a non-prepared surface between concrete cast at different times is sufficient for structural purposes, the vibrated top surface of precast concrete elements which will subsequently receive in situ concrete shall be further prepared using one of the following methods and therefore considered as 'Rough' in accordance to Clause 6.2.5 of I.S. EN 1992-1-1:

Class 1 surface preparation – The surface finish shall be in accordance with sub-Clause 1710.1

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).

The surface classification and the method of preparation shall be shown on the Drawings.

b) Handling and transport. Elements shall be lifted or supported only at points described in Appendix 17/4 and shall be handled and placed without impact. Additional constraints on the support, restraint and dynamic loading during handling or transport are described in Appendix 17/4. The Contractor shall incorporate, in the erection specification, the requirements of the lifting scheme for the precast concrete elements.

c) Storage. When elements are stored, they shall be firmly supported only at the points described in Appendix 17/4. Where elements are stacked several units high, packings shall be vertically above each other to prevent additional bending stresses in the elements, and the maximum height of the stack and any provision required to maintain stability shall be as described in Appendix 17/4. The accumulation of trapped water and deleterious matter in the units shall be prevented. Care shall be taken to avoid rust staining and efflorescence. Where disfigurement would be detrimental, packing pieces shall not discolour or otherwise permanently damage the elements.

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

e) Placing and adjustment. An erection specification shall be prepared by the Contractor in accordance with I.S. EN 13670 and it shall be submitted for acceptance of the Employer's Representative at least 4 weeks prior to the delivery of the elements. The method of assembly and erection shall comply with any particular requirements in Appendix 17/4 and form part of the erection specification.

f) Requirements for placing and adjustment of composite slab bridges. In a composite slab bridge where precast beams are laid side by side with minimal gaps to form a deck, 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, and the width of the deck soffit shall be within + 25 mm of that shown on the Drawings; furthermore, the width of the gap between individual beams shall not exceed twice the nominal gap shown on the Drawings. The alignment of transverse holes shall permit the reinforcement or prestressing tendons to be placed without distortion. In adjacent spans, the continuity of line of the outside beams shall be maintained.
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.

g) Jointing and completion works. 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 erection specification. Levelling devices shall only be released or removed, in accordance with the erection specification, when the structural connection is complete and has achieved sufficient strength.

Care shall be taken to ensure that the in situ material is thoroughly compacted.

When using proprietary jointing materials, the manufacturer's recommendations for the application and methods shall be strictly followed to ensure full compatibility between the joint type and size and the sealing method.

1711 Concrete – Grouting and Duct Systems for Post-tensioned Tendons

Planning, Trials and Basic Requirements

1 Site operations, including duct installation, stressing and grouting, shall be carried out by organisations certificated in accordance with the requirements of the CARES Scheme for the Supply and Installation of Post-tensioning Systems in Concrete Structures, or an equivalent system that complies with I.S. EN 13391. Post-tensioning systems shall be in accordance with Clause 7.2 of I.S. EN 13670.

Grouts for protection of prestressing tendons shall be as required in Appendix 17/6 and defined in sub-Clause 1711.2. Grease and wax for post-tensioned unbonded tendons shall be as required in Clause 1725.

The Contractor shall undertake full-scale trials of the grout mix and of the grouting operations 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 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. The method statement shall also describe arrangements for storage and protection of materials (tendons etc.) on site, in the time between delivery and grouting.

Full scale trials are required and 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 and agreed with the Employer's Representative. 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 Employer's Representative 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 Employer's Representative, 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 and submitted to the Employer's Representative for approval.

Grouting of the ducts shall be shown to leave no void which has a dimension greater than 5% of the duct diameter measured in the radial direction of the duct or which poses a risk to the protective system. The location of any voids with respect to grout vents and their adequate and subsequent sealing, and the disposition of the steel tendons within the body of the grout shall be submitted in writing by the Contractor to the Employer's Representative within 24 days.

Prestressing for the permanent works shall not be permitted without the prior written acceptance of the grouting procedures by the Employer's Representative 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. Inspection and conformity of grouting works, including requirements prior, during and after grouting shall be in accordance with Section 9 of I.S. EN 446 for Execution Class 3.

Grout Materials, Batching and Mixing

2 Grouts shall comply with I.S. EN 447 and with the requirements in this sub-Clause and sub-Clause 1711.3.

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 by the Contractor in accordance with 6.1 of I.S. EN 446. 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 1711.8. 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.

Any proposed changes to previously submitted sources of the materials or trialled procedures shall require re-submission in accordance with the original requirements.

Grouts shall consist only of Portland cement (CEM I) complying with I.S. EN 197-1 Class 42.5N, admixtures complying with sub-Clause 1711.9 and water complying with I.S. EN 1008. Where proprietary prebagged grout is used, they shall be obtained from companies holding a valid CARES certificate for the production of pre-bagged Grouts complying with the Requirements of I.S. EN 445, I.S. EN 446 and I.S. EN 447 (PT10), or an equivalent scheme and it shall be mixed in accordance with the manufacturer's instructions.

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

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):

(i) $\pm$ 2% for dry materials, cement and admixtures

(ii) $\pm$ 1% for mixing water

of the quantities specified. The total amount of mixing water shall include the water content of liquid admixtures. Where proprietary pre-bagged grouts are used, they shall be mixed in accordance with the manufacturer's instructions.

Depending upon environmental or material influence (e.g. 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 water/ cement ratio will normally be in the range 0.3 to 0.4 in order to achieve the performance requirements.

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 $5^{O}C$ and $30^{O}C$. The maximum temperature may be increased provided trials demonstrate that the grout meets the requirements of sub-Clause 1711.8.

Duct Systems

3 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.

Duct Assembly Verification Tests

4 Each complete duct system including vents, anchorages, anchorage caps, and where appropriate couplers and their connections, shall be air-pressure tested before concreting. Testing of 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 2mm. The duct rigidity and type of 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 4mm for durability, or such thicker wall as required to withstand grouting pressures of the particular duct configuration.

The Contractor shall submit evidence of testing to demonstrate the following requirements prior to incorporation in the Works:

(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) 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) The duct system shall comply, as a minimum, with the 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

5 Vents providing an air passage of at least 15mm 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 if full-scale trials demonstrate 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 levelling and shall be protected against damage at all times.

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

Grouting Equipment

6 Grouting equipment shall comply with the requirements of Section 7 of I.S. EN 446.

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. Stand-by and emergency equipment shall be provided.

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

Grouting Procedures

7 Grouting procedures shall comply with the requirements of Section 8 of I.S. EN 446.

Grouting of the ducts shall be carried out within 14 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 written agreement to commence grouting operations shall be obtained from the Employer's Representative.

During grouting operations, once the fluidity of the grout flowing from the vents is the same as the grout being injected (to within the limits specified in I.S. EN 447, as per 8.4 of I.S. EN 446), 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 volume of all grout that is expelled shall be measured. 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/mm2 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 Employer's Representative. 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. Finally, when all outlets are closed the grout pressure shall be maintained for at least one minute to confirm there is no unintended loss due to leakage.

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 Employer's Representative 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 Employer's Representative.

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 Employer's Representative.

If, in the opinion of the Employer's Representative, there is a doubt that the ducts or any part of the system are not satisfactorily filled with grout, the Employer's Representative 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 Employer's Representative within 24 hours of completing grouting to each duct.

On completion of grouting, grout vents shall be positively sealed and waterproofed by a means additional to but separate from the bridge deck waterproofing.

Grouting During Cold or Hot Weather

8 Requirements for grouting in cold or hot weather are given in 8.3 of I.S. EN 446.

When the ambient temperature is expected to fall below $5^{O}C$, 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.

Full details of any proposed method of heating shall be submitted to the Employer's Representative for approval.

Ducts shall not be warmed with steam.

Properties and testing of Grout

9 The properties and performance requirements for grout shall be in accordance with Section 6 of I.S. EN 447. The requirements for suitability testing shall be in accordance with Section 6 of I.S. EN 446. Test methods are described in I.S. EN 445. Test requirements for grout during grouting shall be in accordance with Section 9 of I.S. EN 446 for Execution Class 3.

Admixtures

10 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.

Type

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 Employer's Representative for approval.

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 I.S. EN ISO 9001. The quality system shall be certified by a third party accredited by an appropriate organisation in accordance with sub-Clause 104.3 and 104.4.

Where appropriate, admixtures shall comply with I.S. EN 934-4. Other admixtures shall be permitted provided they satisfy Clause 8 of I.S. 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.

Additional information beyond that required by Clause 8 of I.S. EN 934-2 must be provided by the manufacturer of admixtures in accordance with ZA.2.2 and ZA.3 of I.S. EN 934-2.

Dosage

The optimum dosage of any admixture shall be determined by trail 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.

1712 Reinforcement – Materials

Hot Rolled and Cold Worked Carbon Steel Bars

1 All steel reinforcement specified shall comply with I.S. EN 10080 and BS 4449 (Grade B500B or B500C) and shall be cut and bent in compliance with BS 8666 and shall be obtained from and cut and bent by a firm holding a valid CARES (or equivalent scheme) certificate of approval for production and supply of steel for the reinforcement of concrete.

Hot rolled and cold worked carbon steel bars shall comply with I.S. EN 10080 and BS 4449 except that no bar shall contain a flash weld.

Steel Wire

2 Steel wire shall only be used in precast concrete elements and shall conform to I.S. EN 10080 and BS 4482 (Ribbed, Grade 500). Steel wire shall have a minimum nominal diameter of 8 mm and shall be obtained from a firm holding a valid CARES (or equivalent scheme) certificate of approval for the production and supply of steel wire.

Steel Fabric

3 Steel fabric reinforcement shall conform to I.S. EN 10080 and BS 4483 (Grade B500A, B500B or B500C) and shall be cut and bent in accordance with BS 8666. Steel fabric reinforcement shall have a minimum nominal bar size of 6 mm (8 mm for Grade B500A) and shall be obtained from a firm holding a valid CARES (or equivalent scheme) certificate of approval for the production and supply of steel fabric reinforcement. Steel fabric reinforcement shall be delivered to site in flat mats or pre-bent. The use of Grade B500A reinforcement for steel fabric is permitted only when it is not accounted for at Ultimate Limit State.

Stainless Steel Reinforcement

4 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 equivalent scheme) certificates of approval for the production and supply of stainless reinforcement.

Stainless steel reinforcement shall be ribbed Grade 500 conforming to BS 6744.

Bond Strength

5 For hot rolled and cold worked carbon steel bars, and for steel fabric reinforcement, the bond property requirements of BS 4449 shall be complied with based on the surface geometry requirements of that Standard. For steel wire, the bond property requirements of BS 4482 shall be complied with based on the surface geometry requirements of that Standard.

1713 Carbon Steel Reinforcement and Stainless Steel Reinforcement – Bar Schedule Dimensions – Cutting and Bending

1 The bar schedules are based on the dimensions of the concrete and the nominal cover to the reinforcement shown on the drawings in the Contract. The reinforcement shall be cut and bent within the tolerances given in BS 8666 but this shall not relieve the Contractor of this responsibility for the correct fit of the reinforcement and the achievement of the required cover as described in Clause 1714. The mandrel diameter for bending bars shall comply with Clause 8.3 of I.S. EN 1992-1-1.

Bending of reinforcement at temperatures below $5^{O}C$ or in excess of $100^{O}C$ shall not be carried out.

Re-bending of carbon steel bars and fabric reinforcement on site shall not be permitted.

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 Reinforcement shall be secured against displacement.

The cover to a bar in an outer layer of reinforcement shall be in accordance with Clause 1728.

Bars in inner layers shall be located as shown on the drawings in the Contract; 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 bars shall not be permitted.

Cover shall be achieved by using spacers and chairs which meet the performance requirements of BS 7973-1. They shall be designed so that they will not overturn or be displaced when the concrete is placed. Reinforcement spacers and chairs shall be fixed in accordance with BS 7973-2.

Cementitious Spacer blocks should be factory produced. Site produced concrete or mortar spacers shall not be used.

Wire cast in the block for the purpose of tying it to the reinforcement shall be as described below. Projecting ends of ties or clips shall not encroach into the concrete cover. Tying wires shall be 1.2mm diameter stainless steel wire throughout the structure.

The Contractor shall carry out a cover measurement survey of all reinforced concrete surfaces within the 24-hour period following the removal of formwork and submit the results within a further period of 24 hours. The cover measurement survey shall be carried out on a 500mm grid over the whole structure.

1715 Reinforcement – Surface Condition

1 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 Reinforcement – Laps and Joints

1 Laps and joints shall be made only where shown on the drawings in the Contract. Additional laps or splice bars may only be introduced with the written agreement of the Employer's Representative. The permitted deviation of the lap length from the value stated on the drawings shall be in accordance with Clause 1728.

Where reinforcing bars are required to be coupled, the coupling system shall have a current Irish Agrément Board Certificate or CARES Certificate of Product Assessment TA1-A for use with Road Structures or equivalent certificate and shall be sourced, applied and processed from a firm holding relevant valid CARES (or equivalent scheme) certificate of approval. Couplers shall comply with the cover requirements of sub-Clause 1714.1

1717 Reinforcement – Welding

General

1 Welded reinforcement, other than steel fabric reinforcement, shall not be incorporated in the permanent Works unless permitted in Appendix 17/4. When required, welding of reinforcing bars shall comply with the requirements of Clause 3.2.5 of I.S. EN 1992-1-1, shall be carried out in accordance with I.S. EN ISO 17660 and be subject to the demonstration of the satisfactory performance of trial joints. If the Contractor wishes to propose any other welding of reinforcement the Contractor shall demonstrate to the satisfaction of the Employer's Representative 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.

Strength of Structural Welded Joints

2 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 accredited in accordance with 105.3 and 105.4.

1718 Prestressing Tendons – Materials

Steel Wire and Strands

1 Steel wires and strands shall comply with BS 5896 and shall be obtained from a firm holding a valid CARES (PT6-PT8) certificate of approval for the production of prestressing steel wires and strands, or equivalent scheme.

Cold Worked High Tensile Alloy Bar

2 Cold worked high tensile alloy steel bars for prestressed concrete shall comply with BS 4486 and shall be obtained from a firm holding a valid CARES (PT7) certificate of approval for the production of prestressing steel bars, or equivalent scheme.

Stress-relieved Seven-wire Strand

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

Sampling and Testing

4 When it is proposed to use wire or srtands other than the lowest strength diameter wire or strand complying with BS 5896, 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 BS 5896.

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.

Testing of Prestressing steel bar, wire and strand shall be performed in accordance with I.S. EN ISO 15630-3.

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 any 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.

Protective wrapping for tendons shall be chemically neutral, and suitable protection should be provided for the threaded ends of bars.

When prestressing tendons have been stored on Site for a period of more than 2 weeks, it shall be demonstrated by tests that the quality of the prestressing tendons has not been significantly impaired either by corrosion, stress corrosion, loss of cross-sectional area, or by changes in any other mechanical characteristic.

1720 Prestressing Tendons – Surface Condition

1 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 Works. Slight surface rusting is generally acceptable, unless in environmentally severe sites (marine or industrial).

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 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^{O}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 75mm from the anchor. The temperature of the tendon adjacent to the anchor shall not be greater than 200^{O}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 in the Contract. The position shall be within the tolerances given in Clause 1728.

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 end of ducts shall be sealed and protected after the stressing and grouting operations. Joints in adjacent sheaths shall be spaced at least 300mm 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. Strands of the same diameter but with different strength grades must not be used in the same beam.

Tensioning shall be carried out only in the presence of the Employer's Representative unless he gives written permission to the contrary.

Tensioning Apparatus

2 The tensioning apparatus shall meet the following 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 $\pm$2% and compliance demonstrated to the Employer's Personnel at frequent intervals and additionally as directed. The valid calibration records shall be available on site before tensioning starts.

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

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

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 minimise 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 of 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^{O}.

The transfer of the prestressing force to the concrete shall be effected in conjunction with the release of hold-down and hold-up forces as approved by the Employer's Representative.

Unless otherwise described in Appendix 17/4, concrete shall not be stressed until it has reached at least the age at which 2 test samples taken from it attain the specified transfer strength (as defined in Clause 4.2.3.2.3 of I.S. EN 13369). The test samples shall be made and tested as described in I.S. EN 12390-2 and I.S. 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 samples to demonstrate that the required strength of the concrete at transfer has been reached.

Post-tensioning

4 In addition to the present Clause, the installation of post-tensioning systems shall comply with the requirements of Clause 1711.

(i) Arrangement of tendons. Where wires, strand or bars in a tendon are not stressed simultaneously, the use of spacers shall be in accordance with the recommendation of the system manufacturer.

(ii) Anchorages. Prestressing anchorages for post-tensioning systems shall be in accordance with Clause 7.2 of I.S. EN 13670 and shall be supplied by firms certificated by CARES in accordance with the CARES Scheme for the Production and Supply of Prestressing Anchorages for Post-tensioning Systems (PT3), or an equivalent scheme. Anchorages shall comply with the minimum performance requirements of I.S. EN 13391.

For each anchorage system used in the Works, the characteristic value for anchorage efficiency shall be not less than 95%.

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^{O}.

(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 as agreed with the Employer's Representative. 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^{O}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 samples taken from it (each obtained from the average of two test samples made from one concrete sample) attain the specified transfer strength(as defined in Clause 4.2.3.2.3 of I.S. EN 13369). The test samples shall be made and tested as described in I.S. EN 12390-2 and I.S. 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-jacked 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 unless otherwise stated on the drawings in the Contract. During stressing the value may exceed 70% of their characteristic strength but shall not exceed 80% unless otherwise stated on the drawings in the Contract.

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; however, in the case of deviation from the planned performance during tensioning, cutting of the tendons, grouting and work which can impair the re-tensioning shall not take place until the causes have been investigated and revised tensioning report has been approved.

1725 Prestressing Tendons – Protection and Bond

1 The prestressing tendons shall be protected in their permanent positions from both mechanical damage and corrosion and in accordance with the requirements of Appendix 17/4.

Grout and grouting operations for filling ducts and anchorages of post-tensioned bonded tendons (internal or external) shall be in accordance with Clause 1711.

Grease and wax for the protection of sheaths and anchorages of unbonded tendons shall be in accordance with Clauses 7.2 and 7.6 of I.S. EN 13670.

Vents, grout inlets and outlets and anchorages shall be sealed to assure corrosion protection equivalent to that provided along the tendon. Anchorage zones shall be protected from drainage water.

Unbonded tendons shall be sealed throughout their length against penetration of moisture.

1726 Stainless Steel Dowels – Materials

1 Dowels shall be made from steel Designation 1.4429 or 1.4436 and Grade 200 or 500 steel bars complying with I.S. EN 10080 and BS 6744.

1727 Inspection and Testing of Structures and Components

General

1 Inspection and testing of structures and components shall be in accordance with I.S. EN 13670 for the designated Execution Class (see Clause 1701) and carried out as described in Appendix 17/4 and as scheduled in Appendices 1/5 and/or 1/6. The documentation of inspection shall be in accordance with I.S. EN 13670 and this Specification.

1728 Geometrical Tolerances

General

1 The tolerances given in I.S. EN 13670 and in its Annex and I.S EN 13369 have been derived specifically for buildings and do not apply to Road Works, for which the requirements of the present Clause apply. The tolerances given in this Clause are not cumulative. When required, project specific tolerances shall be as described in Appendix 17/4 and listed on the Drawings.

Irrespective of the use of the following construction tolerances, the use of modified partial safety factors described in Annex A of I.S. EN 1992-1, or Annex C of EN 13369, or other European Product Standards shall not be used.

Reference System

2 The location of the reference grids or primary lines and levels for the overall positioning of the Works shall be agreed by the Employer's Representative and the Contractor before the Works are set out.

Sections

3 The dimensions of cross-section, the cover and position of reinforcement and prestressing tendons shall not deviate more than the values given in Figure 17/1.

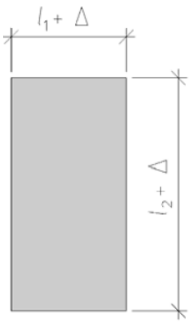
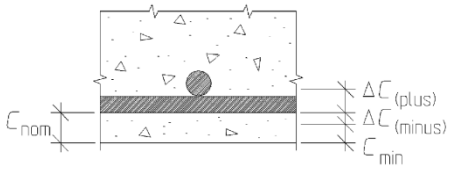
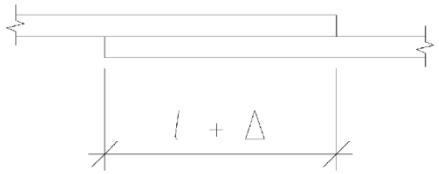
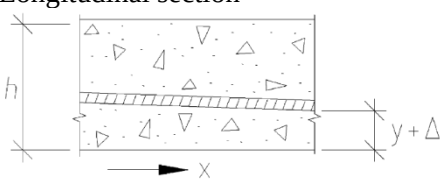
No.	Type of deviation	Description	Permitted deviation Δ
a	Cross-sectional dimensions  	l_i = Length of cross-sectional dimension Applicable to beams, slabs and columns For l_i < 150 mm l_i = 400 mm $l_i \geq$ 2500 mm with linear interpolation for intermediate values	 ± 5 mm ± 10 mm ± 30 mm
b	Location of ordinary reinforcement Cross Section  c_{min} = required minimum cover c_{nom} = nominal cover = c_{min} + | Δc_{dev} | c = actual cover h = height of cross-section Δ = Permitted deviation from c_{nom}	h ≤ 150 mm, h = 400 mm, h ≥ 2500 mm, with linear interpolation for intermediate values	$\Delta_{(plus)}$ = + 5 mm $\Delta_{(plus)}$ = + 10 mm $\Delta_{(plus)}$ = + 20 mm
		All values of h	$\Delta_{(minus)}$ = -5 mm
	Requirement: $c_{nom} + \Delta_{(plus)} > c > c_{nom} - \| \Delta_{(minus)} \|$ Values of $c_{min,dur}$ can be found in DN-STR-03012 Δc_{dev} can be found in National Annex to EN 1992-1-1. See NG 1704.4. NOTE: 1. Permitted plus-deviations for cover to reinforcement for foundations and concrete members in foundations may be increased by 15 mm. The given minus-deviations apply. 2. The definition for $\Delta_{(minus)}$ is not the same as Δc_{dev}.		
c	Lap-joints  	l = Lap length	- 0,06 l
d	Location of prestressing duct Longitudinal section  	y = Intended distance to centreline of duct in plan or elevation	± 5mm

FIGURE 17/1 – Permitted Sectional Deviations

Permitted Deviations at Support Bearings

4 The position of bearings at supports shall not deviate more than the values given in Figure 17/2.

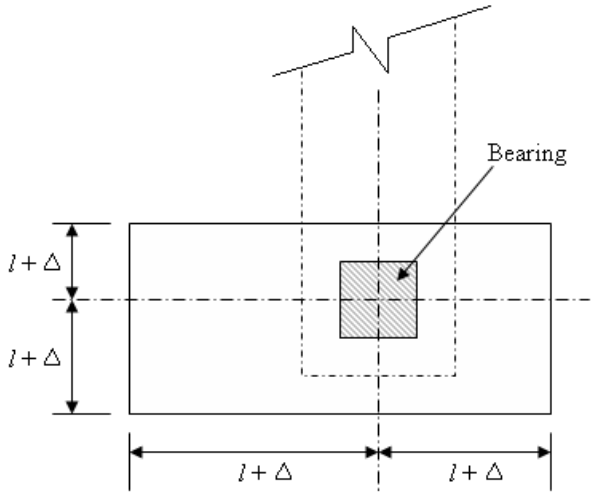
No.	Type of deviation	Description	Permitted deviation Δ
a	Position of bearing axis of support when structural bearings are used 	l = Intended distance from all edges	The larger of |- l/50| or |- 5| mm and not greater than |-15| mm generally, but for columns not greater than the larger of |-15| mm and h/600, where h = free height of column

FIGURE 17/2 – Permitted deviations at support bearings

Permitted Deviations for Columns and Walls

5 The dimensions of columns and walls shall not deviate more than the values given in Figure 17/3.

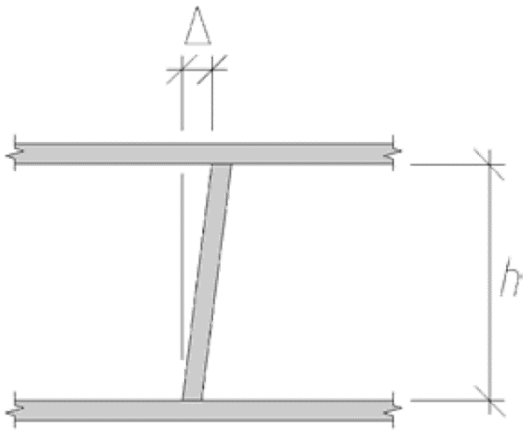
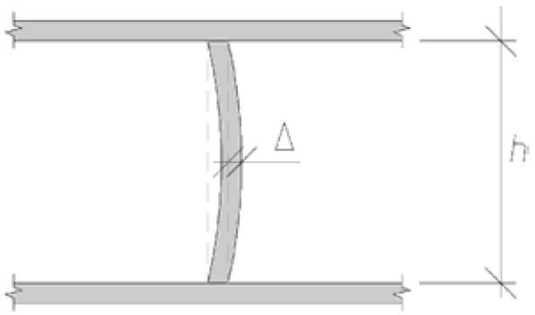
No.	Type of deviation	Description	Permitted deviation Δ
a	Inclination of a column or wall 	h = free height	The larger of h/600 or 15mm
b	Curvature of a column or wall 	h = free height	The larger of h/600 or 15mm

FIGURE 17/3 – Permitted deviations for columns and walls

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