SERIES NG 1700
STRUCTURAL CONCRETE

Contents

STRUCTURAL CONCRETE

NG 1701 (12/14) Concrete – General

(12/14) **Specification of Concrete**

1 (12/14) In the Specification the concept of concrete as a single material has been adopted. It is therefore the responsibility of the designer to specify in contract specific Appendix 17/1 the type of concrete required to ensure both the strength and the durability of the finished structure. By the definitions given in Clause 1702 limitations on the constituent materials are already established.

(12/14) **Designed Concrete**

2 (12/14) Note that both BS EN 206-1 and BS 8500 also cover prescribed and standardized prescribed concretes whilst the latter additionally covers designated and proprietary concretes. Guidance on the specification of designed concrete is given in 4.3 of BS 8500-1 and in 7 of BS 8500-2. The Contractor should be responsible for selecting the constituent material proportions in accordance with Clause 1705 to achieve the required strength and consistence, but the designer is responsible for specifying the minimum cement content, maximum water/cement ratio, the DC-class where appropriate and other properties required to ensure durability in accordance with Clauses 1703 and 1704.

In appropriate circumstances any of the information listed in contract specific Appendix 17/1 may be included, but great care should be taken to ensure that the requirements specified do not conflict with each other.

(12/14) **Requirements for Fresh Concrete**

3 (12/14) Unless specified otherwise the requirements for the concrete in the fresh or plastic state, particularly its consistence, should be selected by the Contractor.

It may be necessary when working in cold or hot weather to control the temperature of fresh concrete (see sub-Clause 1710.6 or 1710.7).

Where the minimum dimension of concrete to be placed at a single time is greater than 600 mm and especially where the cement content is likely to be 400 kg/m^3 or more, measures to reduce the adverse affects of temperature, such as the selection of aggregates with low coefficients of thermal expansion or of a cement type with a slower release of heat of hydration, should be considered. In exceptional cases other measures to reduce the temperature or to remove evolved heat may be necessary.

(12/14) **Implementation of BS EN 13670**

4 (12/14) BS EN 13670 requires an execution specification. The execution specification as defined in BS EN 13670 signifies the total sum of information required for the execution of concrete works. The execution specification is complete if all necessary information is provided. The information need not be compiled in a single document but should be identified and organised such that it can be easily retrieved. The execution specification should be available to those undertaking the work and those involved in supervision and inspection.

BS EN 13670 Annex A, Table A1 contains a checklist of requirements and information to be included in the execution specification as appropriate. Table NG 17/1 indicates where this information can be found or provided for a specific project. The information should be provided within the Specification, on drawings or other documentation required for the execution. The required information may also need to be provided through additional clauses or appendices to the Specification; it should be noted, however, that additional clauses to the Specification are Departures from Standard and will require submission and approval through the Overseeing Organisation's Departure processes.

The requirements of both BS EN 13670 and the Specification must be satisfied. Consequently not all the requirements of BS EN 13670 are referenced in the Specification. BS EN 13670 is not applicable to the manufacture of precast concrete elements made in accordance with Product Standards (Clause 1 of BS EN 13670). However, the provisions of this Specification apply to both in situ and precast concrete (see sub-Clause 1710.8 and NG 1710.8 for provisions for precast concrete construction).

It should be noted that the tolerances given in Section 10 of BS EN 13670 generally apply to building structures and many of them are not relevant for highway works (see sub-Clause 1728.1).

(12/14) **TABLE NG 17/1: Location of information required by BS EN 13670 Annex A, Table A1**

[Note: This Table in its Comments/References column gives the following information relevant to each BS EN 13670 requirement:

a. *Where it is present, the location of existing execution specification information within the SHW.*

b. *Where it is present, the location of NGSHW information for compilers to take into account where appropriate for the works when compiling the contract specific specification.*

c. *When appropriate, where the contract specific information may be included in the relevant contract specific numbered appendix.*

d. *Other advice and guidance for contract specific specification compilers.]*

BS EN 13670		**Requirements**	**Comments/References**
Clause	**Sub-Clause**		
1 Scope	1(2)	Specify all the specific requirements relevant for the particular structure	This requires no specific information and is merely stating that the execution specification should include all project specific requirements.
	1(4)	If required, specify any additional requirements regarding lightweight concrete, other materials (e.g. fibres), constituent materials or special technology	For aspects which are not covered by Series 1700, requirements should be described in contract specific Appendix 17/4 and additional clauses or appendices be included in the Specification in accordance with Clauses NG 000 and NG 003 and subject to the Departure from Standard processes.
	1(5)	State any requirements on concrete members used as equipment for the execution	The execution specification does not apply to concrete members used as equipment or construction aids for the execution.
2 Normative References	2(1)	Add all relevant national Standards or provisions valid at the construction site	Clauses 004, NG 004, 104, NG 104 and Appendix F.
3 Definitions	3.17	Define the reference line for setting out	Clause 112 and contract specific Appendix 1/12.
4 Execution Management	4.1(1)	All necessary technical information to be set out in the execution specification	This requires no specific information and is merely stating that the execution specification should include all requirements.
	4.1(3)	Specify requirements related to qualifications of personnel	Clauses 104 and NG 104. Additional requirements may be listed in the quality plan.
	4.1(4) & 4.2.1(2)	National provisions which need to be respected	Clauses 004, NG 004, 104, NG 104 and Appendix F.
	4.2.1(3)	Include procedure for altering execution specification	The completed execution specification should not be altered.

(12/14) **TABLE NG 17/1: Location of information required by BS EN 13670 Annex A, Table A1 (Continued)**

BS EN 13670		Requirements	Comments/References
Clause	**Sub-Clause**		
4 Execution Management (continued)	4.2.1(3)	Requirements for document distribution	Document control should be covered in the quality plan, as stipulated by contract specific Appendix 1/24.
	4.2.2(1)	State if quality plan required	Required. Refer to Clause 104 and contract specific Appendix 1/24.
	4.2.4(1)	State extent of special documentation if required	The need and extent of special documentation should be covered by additional clauses or appendices to the Specification, in accordance with Clauses NG 000 and NG 003.
	4.3.1(5)	Specify execution class and define who is responsible for the inspection	Clauses 1701.4, NG 1701.6, 1727, NG 1727 and contract specific Appendices 17/4, 1/5 and 1/6.
	4.3.1(6)	Specify provisions related to inspection personnel	Clauses 1727 and NG 1727 and contract specific Appendices 17/4, 1/5 and 1/6.
	4.3.1(7)	If necessary, specify further requirements for the quality management regime	To be detailed in the quality plan if required.
	4.3.2(1) Table 1	Define inspections and acceptance testing of products without a CE-marking or third party certification.	Contract specific Appendices 1/5, 1/6 and 17/4. Reference should be made to Clauses 105, NG 105, 1701.6, NG 1701.6, 1727 and NG 1727.
	4.3.3(1) Tables 2 & 3	Check if the scopes of these inspections are adequate. If not give additional requirements.	Contract specific Appendices 1/5, 1/6 and 17/4. Reference should be made to Clauses 105, NG 105, 1701.6, NG 1701.6, 1727 and NG 1727. Attention is drawn to Clauses 1708 to 1717, NG 1708 to NG 1717, 1724 and NG 1724.
	4.4 (3)	If required specify rectification of possible non-conformances	Clause 104. More detailed actions may also be included in the quality plan as stipulated by contract specific Appendix 1/24.
	5.3(1) and 5.4 (1)	If required specify if method statements shall be worked out	The works for which method statements are required shall be described in contract specific Appendix 1/24. Construction sequence to be detailed on drawings.
	5.3(4)	Specify requirements to temporary support structures, if any	To be stated on drawings or other documentation provided by the designer as appropriate.
	5.4(5)	Specify any requirements for surface finish	Surface finish to be indicated on drawings. Descriptions of surface finish types are given in Clauses 1708 and NG 1708.
	5.4(6)	Specify any requirements for special finishes or trial panels	Special finishes should be described in contract specific Appendix 17/3. Requirements for trial panels are covered by Clause 1708 and contract specific Appendix 17/3 if invoked.

(12/14) **TABLE NG 17/1: Location of information required by BS EN 13670 Annex A, Table A1 (Continued)**

BS EN 13670		Requirements	Comments/References
Clause	**Sub-Clause**		
4 Execution Management (continued)	5.4(7)	Specify any requirement for temporary support of the permanent structure	To be stated on drawings or other documentation provided by the designer as appropriate.
	5.5(1)	Specify any requirements for special formwork	Requirements for special formwork should be described in contract specific Appendix 17/4. Provisions for special formwork may require additional clauses or appendices to be included in the Specification in accordance with Clauses NG 000 and NG 003 and be subject to the Departure processes.
	5.6.2(1)	Requirements for filling temporary holes etc.	To be included on drawings or other documentation provided by the designer as appropriate.
	5.7(1)	Requirements for removal of falsework and formwork to avoid deflections	Sub-Clause 1710.4
	5.7(4)	If relevant, specify sequence of removal, where backpropping and/or re-propping of the structure is used.	To be included on drawings or other documentation provided by the designer as appropriate and detailed in a method statement.
6 Reinforcement	6.2(1)	Specify types of reinforcement	Clause 1712. Type of reinforcement to be indicated on drawings.
	6.2(3)	Specify permitted types of anchorages or couplers	To be indicated on drawings with reference to sub-Clause 1716.2.
	6.2(6)	Requirement for reinforcement materials other than steel if used	Such materials are not covered by Series 1700 and if used, additional clauses or appendices are to be included in the Specification in accordance with Clauses NG 000 and NG 003 and be subject to the Departure processes.
	6.3(1)	Provide cutting and bending schedules or identify that this is a task for the constructor	To be provided by the designer together with the drawings. If cutting and bending schedules are not provided the need for the constructor to do so should be identified through the contract and/or alterations to the Specification as appropriate. Attention is also drawn to contract specific Appendices 1/4 and 1/11.
	6.3(1)	Is bending at temperatures below -5°C permitted and if so specify the precautions to be taken	Sub-Clause 1713.1
	6.3(1)	State if bending by heating is permitted	Clauses 1713 and NG 1713

(12/14) **TABLE NG 17/1: Location of information required by BS EN 13670 Annex A, Table A1 (Continued)**

BS EN 13670		**Requirements**	**Comments/References**
Clause	**Sub-Clause**		
6 Reinforcement (continued)	6.3(2)	Specify mandrel diameters for bending bars	Reinforcement schedules shall indicate the actual radii. Bars shall be bent to and be in accordance with BS 8666, with reference to Clause 8.3 of BS EN 1992-1-1.
	6.3(3)	Specify mandrel diameter for welded reinforcement and fabric bent after welding	Reinforcement schedules shall indicate the actual radii bars shall be bent to and be in accordance with BS 8666, with reference to Clause 8.3 of BS EN 1992-1-1.
	6.3(5)	Specify any requirements to straighten bent bars	Clause 1713
	6.4(1) & 6.4(2)	Provisions for welding of reinforcement	Clause 1717
	6.4(3)	Specify if spot welding is permitted	Not permitted unless otherwise stated in contract specific Appendix 17/4 and subject to satisfactory trial joints. Clauses 1717 and NG 1717.
	6.5(1)	Specify the position of reinforcement including cover, the position of laps and joints etc.	To be indicated on drawings. Attention is drawn to Clauses 1714 and 1716.
	6.5(2)	Specify if reinforcement *by running metres* is permitted	To be indicated on drawings. Attention is drawn to Clauses 1714 and 1716.
	6.5(3)	Specify special requirements if any to assembly and fixing of reinforcement	Clauses 1714 and NG 1714.
	6.5(4)	Specify nominal concrete cover, i.e. the required minimum cover + the numerical value of the permitted minus-deviation	Nominal cover to be stated on drawings. Permitted minus deviation given in sub-Clause 1728.3. See also sub-Clause NG 1704.4.
7 Prestressing	7.1(2)	Requirements for installation of post-tensioning kits and qualification of personnel to perform the installation	Sub-Clause 1711.1 with reference to Clauses 104, NG 104 and the quality plan.
	7.2.1(1)	Requirements to the post-tensioning system	Reference is made to Clauses 1724, 104, NG 104 and the quality plan.
	7.2.3(1)	Specify requirements for the prestressing steel	Clause 1718. Type to be indicated on drawings.
	7.2.3(2)	State if alternatives to prestressing steel are permitted, and the requirements	Alternatives are not covered by Series 1700 and if used, additional clauses or appendices are to be included in the Specification in accordance with Clauses NG 000 and NG 003 and be subject to the Departure processes.

(12/14) **TABLE NG 17/1: Location of information required by BS EN 13670 Annex A, Table A1 (Continued)**

BS EN 13670		**Requirements**	**Comments/References**
Clause	**Sub-Clause**		
7 Prestressing (continued)	7.2.5(2)	Description of tendon support	To be described on drawings or other documentation provided by the designer.
	7.4.1(1)	Provisions for assembling of prestressing tendons	Clause 1723
	7.4.1(3)	Specify if welding of local anchorage zone reinforcement, anchor plates and spot welding of perforated plates is permitted	Clauses 1717 and NG 1717. Welding of anchor plates or perforated plates is not permitted by the Specification.
	7.5.1(3)	Identify stressing anchors and passive/dead end anchors	To be indicated on drawings.
	7.5.1(6)	Requirement relating to minimum compressive strength of concrete when application and/or transfer of prestressing force to the structure	To be indicated on drawings.
	7.5.2(1)	Actions to be taken when accuracy of elongation of pre-tensioning tendons cannot be achieved	Cause to be investigated and a solution agreed with the Overseeing Organisation, which may lead to subsequent re-tensioning to be carried out. Reference should be made to Clause 1724.
	7.5.3(1)	Actions to be taken when accuracy of elongation of post-tensioning tendons cannot be achieved	Cause to be investigated and a solution agreed with the Overseeing Organisation, which may lead to subsequent re-tensioning to be carried out. Reference should be made to Clause 1724.
8 Concreting	8.1(1)	Check that all the required concrete properties have been specified according to EN 206-1 and national Standards or provisions valid in the place of use of the concrete	Clause 1701 and contract specific Appendices 17/1 or 17/4 as appropriate.
	8.1(3)	State the minimum upper sieve size, D, for the concrete	Contract specific Appendix 17/1 and NG 1702.2.
	8.2(1)	State if a concreting plan is required	Contract specific Appendix 1/24 indicates what concrete works method statements are required for.
	8.2(2)	State if a trial casting is required	Sub-Clause 1708.1 and contract specific Appendix 17/3. If there are special requirements, additional clauses or appendices are to be included in the Specification in accordance with Clauses NG 000 and NG 003 and be subject to the Departure processes.

(12/14) **TABLE NG 17/1: Location of information required by BS EN 13670 Annex A, Table A1 (Continued)**

BS EN 13670		Requirements	Comments/References
Clause	**Sub-Clause**		
8 Concreting (continued)	8.2(4)	State requirements to construction joints where relevant	Reference is made to sub-Clauses 1710.1, NG 1710.1 and contract specific Appendix 17/4.
	8.2(6)	State if an increased cover to the reinforcement is needed when casting directly on ground	Reference is made to Clauses NG 1703, NG 1704 and contract specific Appendix 17/5. Indicate on drawings.
	8.3(4)	State if samples shall be taken	Reference is made to Clauses 1707, NG 1707 and contract specific Appendix 17/4
	8.3(5)	State if contact with aluminium alloy is permitted e.g. aluminium	Reference is made to Clause 1710.3.
	8.4.4(1)	If sprayed concrete is applied, the execution specification shall be according to EN 14487	Sprayed concrete is not covered by Series 1700 and, if required, additional clauses or appendices are to be included in the Specification in accordance with Clauses NG 000 and NG 003 and be subject to the Departure processes.
	8.4.5(2)	If slipforming is applied, the detailing shall be compatible with the equipment	Sub-Clauses 1710.3 and NG 1710.3.
	8.4.6(1)	Specify special requirements to underwater casting, methodology etc. if any	Sub-Clause 1710.3. It should be noted that underwater concreting is not covered in detail by Series 1700 and, if required, additional clauses or appendices may need to be included in the Specification in accordance with Clauses NG 000 and NG 003 and be subject to the Departure processes.
	8.4.6(2)	If the concrete is to be cast underwater, the detailing and the concreting method shall be compatible	Sub-Clause 1710.3. It should be noted that underwater concreting is not covered in detail by Series 1700 and if used additional clauses or appendices may need to be included in the Specification in accordance with Clauses NG 000 and NG 003 and be subject to the Departure processes.
	8.5(2)	Specify if there are any need to protect the concrete in its early age from aggressive agents	This is not covered by Series 1700 and if necessary, additional clauses or appendices are to be included in the Specification in accordance with Clauses NG 000 and NG 003 and be subject to the Departure processes.
	8.5(7)	Specify the curing class to be applied	Sub-Clause 1710.5 and contract specific Appendix 17/4

(12/14) **TABLE NG 17/1: Location of information required by BS EN 13670 Annex A, Table A1 (Continued)**

BS EN 13670		Requirements	Comments/References
Clause	**Sub-Clause**		
8 Concreting (continued)	8.5(8)	Specify if any special curing requirements	Special curing requirements should be included in contract specific Appendix 17/4. Reference should also be made to sub-Clause 1710.5.
	8.5(16)	Specify if special measures to reduce the risk of thermal cracking are needed	To be indicated in contract specific Appendix 17/1. Reference is made to Clauses NG 1701.3, NG 1702.2, 1704.7, NG 1704.7, NG 1704.12, NG 1710.4, NG 1710.5 and NG 1710.7.
	8.8(1)	Specify possible surface finish requirements	Surface finish to be indicated on drawings. Descriptions of surface finish types are given in Clauses 1708 and NG 1708 or contract specific Appendix 17/3 if contract specific surface finishes are to be used.
9 Execution with precast concrete	9.1(2)	Specify the precast concrete elements to be used	To be indicated on drawings and other documentation provided by the designer, with reference to contract specific Appendix 17/7.
	9.4.1(1) and 9.4.1(3)	Specify special requirements to handling, storage, protection and position	Clauses 1710.8 and contract specific Appendix 17/7. Further information may be in the erection specification.
	9.4.2(3)	Specify requirements to product identification	Clause 1710.8. Further information may be in the erection specification.
	9.5.1(1)	Requirements for placing and adjustments	Clauses 1710.8, NG 1710.8 and contract specific Appendix 17/7. Details to be included in erection specification.
	9.5.2(4)	Input for the erection if relevant	Reference made to Clauses 1710.8 and NG 1710.8. Erection details to be included in erection specification, execution specification and works programme
	9.6	In situ works required for completion	To be detailed on drawings or other documentation provided by the designer.
	9.6.3(1)	Detailing of structural connections	To be detailed on drawings or other documentation provided by the designer.
	9.6.3(2)	Specify acceptable specific technologies	To be detailed on drawings or other documentation provided by the designer, with reference to contract specific Appendix 17/7. If necessary additional clauses or appendices are to be included in the Specification in accordance with Clauses NG 000 and NG 003 and be subject to the Departure processes.

(12/14) **TABLE NG 17/1: Location of information required by BS EN 13670 Annex A, Table A1 (Continued)**

BS EN 13670		Requirements	Comments/References
Clause	**Sub-Clause**		
9 Execution with precast concrete (Continued)	9.6.3(3)	Specify requirements to joints, inserts for joint connections and welded structural connections	To be detailed on drawings or other documentation provided by the designer, with reference to contract specific Appendix 17/7. If necessary additional clauses or appendices are to be included in the Specification in accordance with Clauses NG 000 and NG 003 and be subject to the Departure processes.
10 Geometrical tolerances	10.1(2)	Specify if tolerance class 2 applies	Clauses 1728 and NG 1728. Tolerance class 2 does not routinely apply. The requirements for tolerances are detailed in Clause 1728 and tighter or additional tolerances, if required, should be detailed in contract specific Appendix 17/4.
	10.1(2) and 10.1(4)	Specify any special tolerances and the elements to which they apply	Any special tolerances are to be included on drawings or other documentation provided by the designer.
	10.1(3)	Specify if the tolerance requirements in Annex G do not apply	Reference made to sub-Clauses 1728.1 and NG 1728.1. Annex G tolerance requirements do not apply. The requirements for tolerances are detailed in Clause 1728 and tighter or additional tolerances, if required, should be detailed in contract specific Appendix 17/4.
	10.1(4) and 10.1(5)	Specify if "box-principle" apply and with what tolerance, if different from ± 20 mm	Box-principle does not apply.
	10.1(6)	State any requirements for surfaces with full contact bearing	Requirements to be indicated in contract specific Appendix 17/4 and on drawings.
	10.1(7)	Specify tolerances for sections that are to be cast underwater	Requirements to be indicated in contract specific Appendix 17/4 and on drawings.
	10.1(10)	Possible requirements for the combination of construction tolerances and structural deflections	Any special requirements for combination of construction tolerances and structural deflections to be included in contract specific Appendix 17/4 and on drawings.
	10.2(3)	State any requirements for secondary lines	Clause 1728.2.

(12/14) **Execution Class**

5 (12/14) Three execution classes are given in sub-Clause 4.3.1 of BS EN 13670. With regards to the type of inspection of execution (sub-Clause 4.3.3 of BS EN 13670), Execution Class 3 requires, in addition to visual inspection, detailed inspection of all works which are significant for the load-bearing capacity and durability of the structure, whereas Execution Class 2 only requires systematic and regular measurements of major works. For highway structures, it is considered that a detailed inspection of all works which are significant for the load bearing capacity and durability of the structure is appropriate, and therefore Execution Class 3 should be the default requirement.

(12/14) **Inspection Requirements**

6 (12/14) Documentation of inspection is closely linked to execution documentation and quality records. The locations of some of the key requirements are given in Table NG 17/1. See also NG 1727. With regards to the party which carries out the inspection, Table 3 of BS EN 13670 implies that, for Execution Class 3, additional requirements to self inspection and inspection in accordance with the procedures of the constructor should be considered, i.e. an independent inspection; this requirement is however relaxed in Annex B of BS EN 13670. Therefore, for highway structures built in accordance with Execution Class 3, an independent inspection is not routinely required, unless this is specifically required by the designer and parts of the structures are designated as Inspection Level 3 to BS EN 1990, based on the complexity of the structure and the criticality of the execution for its ability to fulfil its function. Where an independent inspection is required, requirements regarding who is to procure it should be included in Appendix 17/4 along with requirements for the Overseeing Organisation's agreement.

NG 1702 (12/14) CONCRETE – CONSTITUENT MATERIALS

(12/14) **Cement**

1 (12/14) CEM III/B or CIIIB are used where considered appropriate, for example, for special applications such as sulfate resistance of buried concrete, to help minimise the risk of thermal cracking and where high resistance to chloride ingress is required. However, they should not be used in the surfaces of exposed concrete where there is a risk of surface scaling under conditions of freezing and thawing.

Sulfate-resisting Portland cement was previously specified to BS 4027 as SRPC; BS 4027 has been withdrawn and allowed sulfate-resisting Portland cements are now CEM I-SR 0 (with C3A content of the clinker = 0%) and CEM I-SR 3 (with C3A content of the clinker ≤ 3%), specified to BS EN 197-1.

Calcium aluminate cement (CAC) to BS EN 14647, colloquially and previously known as high alumina cement (HAC) to BS 915-2, does not appear in the Specification and its use is not permitted.

The use of blended cements containing fly ash or ground granulated blastfurnace slag may increase concrete durability and resistance to both chloride ingress and sulfate attack. However, care should be taken due to possible delayed strength development and particular attention should be paid to curing in accordance with sub-Clause 1710.5.

General suitability as a Type I (nearly inert) and Type II (pozzolanic or latent hydraulic) addition is defined in 4.4 of BS 8500-2.

(12/14) **Aggregates**

2 (i) (12/14) General. In general the aggregates specified in sub-Clause 1702.2 of the Specification should be used. In exceptional circumstances and for particular special applications the designer may specify the use of aggregates other than those specified in sub-Clause 1702.2, including types or gradings not covered by the appropriate British Standards, provided that there are satisfactory data on the properties of concrete made with them.

Recycled concrete aggregate (RCA) and recycled aggregate (RA) are excluded from the Specification until further evidence is collected to establish the long term durability to structures containing RCA and RA exposed in aggressive environments, especially chloride-bearing environments. In accordance with the provisions of BA 92 'The use of recycled concrete aggregate in structural concrete' (DMRB 2.3.9), the use of RCA as a replacement for natural coarse aggregate is allowed within specific limitations and for particular applications; however, its specification would require submission and approval through the Overseeing Organisation's Departures processes.

Guidance on the use of BS EN 12620 and BS EN 13055-1 and the specification of aggregates for concrete in the UK is given in PD 6682-1 and PD 6682-4. Under Construction Products Regulation (CPR), 'Assessment and Verification of Consistency of Performance' (AVCP) replaces 'Attestation of Conformity' used under the Construction Products Directive (CPD). See Clause NG 104.

When high strength concrete is required, and depending on how high the strength is specified, the potential concrete supplier should be advised of the requirements as soon as possible. This is because the source as well as the type of aggregate may need careful assessment, and may need some initial testing. Further guidance on high strength concrete can be found on the Concrete Bridge Development Group Technical Guide 6 'High strength concrete in bridge construction'.

Where it is known that any property of any aggregate is likely to have an unusual effect on the strength, density, shrinkage, moisture movement, thermal properties, creep, modulus of elasticity or durability of concrete made with it, the designer should take account of these factors in the design and workmanship requirements.

Requirements for the evaluation of conformity and frequency of testing for aggregates are given in BS EN 16236.

The ten per cent fines test for resistance of coarse aggregate to fragmentation has been replaced by the Los Angeles test given in BS EN 1097-2 but there is no direct correlation between the test methods. The Los Angeles coefficient is declared in accordance with the relevant category specified in Table 16 of BS EN 12620. Clause 4.3 of BS 8500-2 requires that the Los Angeles coefficient category should be the category specified in the project specification or, where a category has not been specified, it should meet the requirements of LA40. However, this limitation may exclude perfectly usable materials and BS 8500-2 also recognises that aggregates with LA coefficient values above 40 may also perform satisfactorily in normal concrete but recommends that their strength performance be established in concrete trials before use.

Aggregates having a high drying shrinkage, such as some dolerites and whinstones, and gravels containing these rocks produce concrete having a higher drying shrinkage than that normally expected. This can result in deterioration of exposed concrete and excessive deflections of reinforced concrete unless special measures are taken. BS 8500-2 requires the aggregate drying shrinkage to be not more than 0.075% when determined in accordance with BS EN 1367-4.

When air cooled blastfurnace aggregate conforming to BS EN 12620 is used, sampling and testing should be carried out at sufficiently frequent intervals to confirm the bulk density. Despite initial compliance with the minimum density, substantial variation above this minimum can change the characteristics of the concrete mix if the weights of the aggregates are kept constant. If such variations occur, the mix should be adjusted to allow for them. Further advice on this subject can be obtained from the Building Research Establishment.

(ii) (12/14) Maximum aggregate size. The preferred maximum aggregate sizes of aggregate are 40 mm and 20 mm, but if a smaller size is necessary it should be 10 mm.

(12/14) **Admixtures and Pigments**

3 (i) (12/14) General. Admixtures should be specified by type and include any limiting values of essential characteristics for these materials that are appropriate for the satisfactory execution of the works. Many admixtures are highly active chemicals and may impart undesirable as well as desirable properties to the hardened concrete; their suitability should generally be verified by initial testing. The initial testing should contain cement of the same make and type and from the same source as that intended to be used for the permanent works. If two or more admixtures are thought to be required in any one mix, the manufacturer of each should be consulted. The trials should confirm that the admixture is compatible with all the other constituents of the concrete and show whether it accelerates or retards the setting time and results in any loss of consistence. It should be noted that these materials are potentially harmful to people, and designers need to be alert to this when specifying their use.

Only in exceptional circumstances, for example in exceptionally hot weather, should retarders be used in structural concrete. Consideration may be given to their use in grouts for prestressing tendons, especially in hot weather (see NG 1711.1).

(ii) (12/14) When a concrete of Class 32/40 or lower is subject to freezing when wet and/or subject to the effects of salt used for de-icing, it should contain entrained air.

The carbon contained in fly ash and certain pigments can substantially reduce the effectiveness of some air-entraining agents. This does not usually create a problem but care may have to be taken when using these materials. In some cases it may be necessary to increase appreciably the amount of admixture used. The amount of air entrained in a designed concrete can also be affected by many other factors, among which are:

(a) Type and amount of admixture used.

(b) Consistency of the concrete.

(c) Concrete proportions.

(d) Type and grading of the aggregate.

(e) The length of time for which the concrete is mixed.

(f) Temperature. In the range 10°C to 30°C an increase of 10°C can reduce the amount of entrained air by about 25%.

(g) The cement type, source, fineness and cement content of the concrete.

(12/14) **Fibres for concrete**

4 (12/14) Guidance on the use of fibres can be found in the Concrete Society Technical Reports 63 ‘Guidance for the design of steel-fibre-reinforced concrete’ and 65 ‘Guidance on the use of macro-synthetic-fibre-reinforced concrete’. Where the use of steel and polymer fibres conforming to BS EN 14889 as reinforcement for concrete is considered appropriate, the requirement should be described in contract specific Appendix 17/4 and their specification would require submission and approval through the Overseeing Organisation’s Departures processes (NG 1701.4 and Table NG 17/1).

NG 1703 (12/14) Concrete – Exposure Classes

1 (12/14) Environmental and ground conditions are classified as exposure classes in Tables A.1 and A.2 of BS 8500-1. Table A.1 gives a non-exhaustive list of examples applicable in the United Kingdom. All relevant exposure classes pertaining to the structure or structural element should be identified. There can be specific structures or elements where the exposure does not readily fit the descriptions given in the exposure classes. In such situations, designers should use design judgment for that application. Particular attention should be given to culverts, subways, large horizontal exposed surfaces, exposed edges of decks, cantilever deck edges and retaining walls. There may be situations where more severe exposure classes should be considered, such as the underside of in situ concrete cantilever deck edges or road over road bridges, where the soffits may be affected by salt spray from the road carried by the bridge, as well as from the road crossed.

Table A.1 of BS 8500-1 gives informative examples of XD1 exposure including bridge soffits more than 5 m vertically above the carriageway. In most cases, notably for precast concrete beams and concrete sheltered between concrete beams or steel girders, this will be adequate. Concrete below an effective waterproofing system on bridge decks should be considered as XC3 exposure, and this aligns with the provision of the UK National Annex for the note 105 to 4.2 of BS EN 1992-2. It should be noted that exposed faces of bridge deck concrete may determine the concrete mix design requirements. For further guidance regarding the role of permanent formwork in determining cover to reinforcement see sub-Clause NG 1704.4

Since the final concrete requirements are dependent on the exposure classes, contract specific Appendix 17/1 makes allowance for the relevant exposure classes to be listed, but they do not form part of the concrete specification except for DC-classes.

Where chemical attack of buried concrete needs to be considered, the aggressive chemical environment for concrete (ACEC-class) derived from Table A.2 of BS 8500-1 should be converted to a design chemical class (DC-class) and, where appropriate, number of additional protective measures (APMs) adopted, as detailed in Tables A.9, A.10 and A.11 of BS 8500-1. See sub-Clause NG 1704.11 and the BRE Special Digest 1 for further guidance.

NG 1704 (12/14) Concrete – General Requirements

(12/14) General Considerations

1 (12/14) The minimum requirements for the strength and durability of the concrete in the hardened state should be decided by the designer from the requirements of the relevant structural design code and the guidance in NG 1704, but if in addition a special property or a particular surface finish is required, these minimum requirements may have to be considerably exceeded.

The strength class of concrete required depends partly on the particular use and the characteristic strength needed to provide the structure with adequate ultimate strength and partly on the exposure conditions and the cover provided to any reinforcement or tendons.

(12/14) Compressive Strength Class of Concrete

2 (12/14) Compressive strength is specified according to BS EN 206-1 and BS 8500 by a dual classification comprising the characteristic strength of 150 mm diameter by 300 mm length cylinders followed by the characteristic strength of 150 mm cubes, e.g. C20/25. BS 8500 treats the strength of concrete measured on 100 mm and 150 mm cubes as being identical and therefore in UK the dual classification applies also to 100 mm cubes. Clause 4.3 of BS EN 206-1 and Table 9 of BS 8500-2 give recommended strength classes to be used in specifications in the UK. Note that BS 8500 contains some extra classes compared with BS EN 206-1.

(12/14) Intended Working Life

3 (12/14) For the selected intended working life and nominal cover to reinforcement, Tables A.4 to A.12 of BS 8500-1 give guidance on the limiting values for composition and properties of concrete, when using a particular maximum size of aggregate, to provide acceptable durability for each identified exposure class. For exposure classes relating to the risk of corrosion of reinforcement induced by carbonation (XC classes) and by chlorides, either from sea water (XS classes) or sources other than sea water such as de-icing salts (XD classes), these limiting values are given in Tables A.4 and A.5 for intended working lives of at least 50 years and at least 100 years respectively. For exposure classes relating to the environmental action of freezing and thawing (XF classes), the given limiting values in Table A.8 are considered to be suitable for an intended working life of at least 100 years.

For highway structures with a design life of 120 years, the use of concrete complying with the requirements of BS 8500 for an intended working life of at least 100 years will be accepted. However, it must be noted that there is a higher degree of uncertainty with the recommendations for an intended working life of at least 100 years in the chloride (XD) and sea water (XS) environment, than that associated with the 50 years recommendations, and reliance solely on cover and concrete quality might not be the most economic solution. Consideration may be given to using other techniques such as stainless steel or non-ferrous reinforcement; further guidance is given in the Concrete Society Technical Report 61 ‘Enhancing reinforced concrete durability’.

Since the final concrete requirements are dependent on the intended working life of the structure, contract specific Appendix 17/1 makes allowance for this to be given but it does not form part of the concrete specification.

(12/14) **Cover to Reinforcement**

4 (12/14) Tables A.4 and A.5 of BS 8500-1, covering XC, XD and XS exposures where reinforcement corrosion is the deterioration mechanism, give a range of options for limiting values for the composition and properties of concrete, related to the cover to reinforcement. The recommendations given to resist freezing and thawing and chemical attack are such, that when combined with the XC, XD and XS forms of attack, the cover to reinforcement does not need to be increased, unless a sacrificial layer has been selected to resist chemical attack, in which case the cover should be increased by the layer thickness. However, where freeze-thaw resistant aggregates are required, the concrete mix composition may be affected and this should be taken into account as appropriate.

The cover to reinforcement is given, as nominal cover, in the form X + Δc where X is the minimum cover (i.e. the highest value between the minimum cover required for durability, transmission of bond forces and fire resistance, as per BS EN 1992-1-1 and A.3 of BS 8500-1) and Δc is a tolerance to accommodate fixing precision. Where on a bridge deck it is permitted by the requirements in the DMRB not to apply a waterproof membrane, it should be noted that BS EN 1992-2 requires the minimum cover to be increased by 10 mm for bare concrete decks of road bridges without waterproofing or surfacing where a concrete surface is subject to abrasion caused by ice or solid transportation in running water, and by 5 mm for uneven surfaces (e.g. exposed aggregate). Where stainless steel is used, the minimum cover for durability may be relaxed (see sub-Clause NG 1712.2).

With reference to the provisions for the geometric tolerances given in sub-Clause 1728.3, that originate from the BS EN 13670, the tolerance Δc in BS 8500 represents the $\Delta_{(minus)}$, i.e. the permitted negative deviation from the nominal cover, to be taken equal to the Δc_{dev} given in BS EN 1992-1-1 and BS EN 1992-2. BS 8500-1 advises that Δc typically lies within the range 5 mm to 15 mm. In most in situ concrete construction applications Δc should be 10 mm, as recommended in the UK National Annex to BS EN 1992-1-1, unless a lesser tolerance can be justified in special cases, such as deck slabs of less than 150 mm thickness. If this is adopted, it should be expressly stated within contract documentation and drawings. Additional checks would be required on site to ensure compliance and methods to achieve this should be detailed in Contractors' site practices and agreed method statements.

For precast concrete elements (see sub-Clause 1710.8), the fixing tolerances Δc should be as recommended in Table 4 of BS EN 13369; in particular, $\Delta_{(minus)}$ should lie between 5 and 10 mm. However, certificates of compliance should be sought from precast concrete suppliers to ensure that such tolerance is justifiable and achieved.

Designers' attention is drawn to section A.3 of BS 8500-1 which describes a rationale for dealing with the role of permanent formwork in determining cover. Where participating reinforced concrete plank permanent formwork systems are proposed, in most normal situations exposure class XD1 should be applied to the concrete plank itself, in terms of cover requirements and concrete quality. A minimum of 20 mm cover should also be provided from the upper surface of the concrete plank to the reinforcement in the in situ concrete slab above, to allow rebar to be fully surrounded by concrete. Where a thoroughly tested and fully sealed ribbed glass reinforced polymer (GRP) non-participating permanent formwork system is selected, the exposure class XD1 should be applied to the in situ concrete above the permanent formwork, in terms of cover requirements and concrete quality. Where the GRP ribs protrude into the concrete, the cover should be measured from the horizontal GRP/concrete interface, provided that at least 20 mm is also provided between the top of the rib and the nearest reinforcement, to allow rebar to be fully surrounded by concrete.

The nominal cover, including the fixing tolerances should be clearly stated in contract specific Appendix 17/1. Since the final concrete requirements are dependent on the cover to reinforcement, contract specific Appendix 17/1 makes allowance for the nominal cover to be given, but it does not form part of the concrete specification. It would be advisable to add notes to the drawings indicating the nominal cover and the permitted negative and positive deviations.

For the purpose of calculating crack widths as part of the design process in accordance with BS EN 1992-1-1 and BS EN 1992-2, the value of the cover utilised should be the nominal cover (including any additions for service life), although in some situations, such as structures cast against the ground where there are no appearance requirements, it is reasonable to determine the crack width at the cover required for durability and verify that it does not exceed the relevant maximum crack width.

(12/14) **Selection of Limiting Values for Concrete Composition and Properties**

5 (12/14) Having identified the limiting values for concrete composition and properties relevant to all identified exposure classes pertaining to the particular structure element, these values should then be compared and the most onerous values selected and specified. Values selected should be the highest strength class, the lowest maximum w/c ratio, the highest minimum cement/combination content and cement/combination types that are suitable for all the identified exposure classes. It should be noted that whereas BS EN 206-1 requires the exposure class(es) to be specified as a description for a set of concrete requirements given in national provisions, BS 8500 requires the specification of designed concrete to contain the required limiting values (or the DC-class in the case of exposure classes for chemical attack). The reasons for this difference are given in 4.3.2 of BS 8500-1.

However, considerable care must be exercised in selecting the final limiting values for the designed concrete, to ensure that a viable designed concrete is achieved. This is particularly the case where diverse exposure conditions apply to a structural element e.g. an abutment subject to chloride attack on the front exposed face and the rear face buried in highly aggressive ground conditions.

(12/14) **Minimum Cement Content and Maximum Water/Cement Ratio**

6 (12/14) The designer should state in contract specific Appendix 17/1 the minimum cement content required for each concrete. One of the main characteristics influencing the durability of any concrete is its ability to absorb water. With strong dense aggregates, a suitably low absorption is achieved by having a sufficiently low water/cement ratio, by ensuring sufficient hydration of the cement through proper curing methods, and by ensuring maximum compaction of the concrete. Therefore for given aggregates the cement content should be sufficient to provide adequate consistence with a low water/cement ratio so that the concrete can be fully compacted with the means available. Water reducing admixtures conforming to BS EN 934-2 can be beneficial in reducing the free water/cement ratio.

Tables A.4 to A.12 of BS 8500-1 apply to concrete made with cements described in sub-Clause 1702-1. The cement contents may need to be greater than the minimum values given in BS 8500-1 when trial mixes (see NG 1705.2) indicate that this is necessary for:

(i) the consistent production of a concrete with a maximum free water/cement ratio not greater than that given for a particular condition; and

(ii) the conditions of placing and compaction.

(12/14) **Maximum Cement Content**

7 (12/14) Cement contents in excess of 550 kg/m³ should not be used unless special consideration has been given in design to the increased creep, risk of cracking due to drying shrinkage in thin sections, and higher thermal stresses in thicker sections. For higher strength classes of lightweight aggregate concrete, cement contents in excess of 550 kg/m³ may be used provided that the concrete produced is suitable in all respects.

(12/14) **Maximum Chloride Content**

8 (12/14) The maximum chloride content of concrete is specified by means of a chloride class. Relevant classes are given in Table 17/1. BS 8500-1 adds extra advice on the chloride class required for post-tensioned concrete structures. It is emphasized that, while for internal post-tensioned office construction a chloride class of Cl 0,40 is appropriate, for bridges and strategic structures in severe chloride environments a chloride class of Cl 0,10 shall be used. The methods for determining the chloride content of constituent materials shall be in accordance with Table 4 of BS 8500-2.

Sulfate-resisting Portland cement was previously specified to BS 4027 as SPRC; BS 4027 has been withdrawn and allowed sulfate-resisting Portland cements are now CEM I-SR 0 (with C_3A content of the clinker = 0 %) and CEM I-SR 3 (with C_3A content of the clinker ≤ 3%), specified to BS EN 197-1.

(12/14) **Maximum Sulfate Content**

9 (12/14) Sulfates are present in most cements and in some aggregates; excessive amounts can cause expansion and disruption in the concrete. However, as no tests exist to determine mobile sulfate content, it is usual to measure the acid soluble sulfate content of cements and aggregates. The relationship between such measurements and the mobile sulfate content of the hardened concrete is variable and therefore no universal sulfate limit can sensibly be applied to concrete.

(12/14) **Control of Alkali Silica Reaction**

10 (i) (12/14) It is generally accepted that alkali-silica reaction can only occur if reactive minerals are present, the alkali level of the concrete is above a certain level and a sufficient supply of water is available. For concrete highway structures it must be assumed that sufficient water will be available so that aggregate types and alkali levels must be controlled. Most cases of alkali-silica reaction appear to be associated with the use of high alkali cements.

(ii) (12/14) Requirements to minimise the occurrence of alkali silica reaction are part of the general requirements of BS 8500-2. These are largely based on the guidance given in Building Research Establishment BRE Digest 330 Parts 1 – 4.

(iii) (12/14) Extremely reactive aggregates, comprising those aggregates containing detectable quantities of opal, glass and calcined flint, should not be used alone or in combination with other aggregates.

(12/14) **Buried Concrete Exposed to Sulfates**

11 (i) (12/14) The limiting values for some of the exposure classes for chemical attack and some of the test methods in BS EN 206-1 vary from current United Kingdom practice. The recommendations in BS 8500 to protect buried concrete exposed to sulfates are based on Building Research Establishment Special Digest SD1 ‘Concrete in Aggressive Ground’ which covers a wider range of environmental actions than BS EN 206-1 and includes mobile ground water, acids and brownfield sites. The recommendations give precautions to minimise the risk of the occurrence of the thaumasite form of sulfate attack (TSA) as well as the conventional ettringite form of sulfate attack. The precautions take the form of designed concrete options with, where appropriate, additional protective measures. The designed concrete options are now dependent upon a parameter termed the design chemical (DC) class.

The DC-class is derived as follows:

Consideration of the sulfate and magnesium ion concentration in the soil or groundwater gives the design sulfate class (DS-class). It should be noted that it is also necessary to take account of the ‘potential’ sulfate that can arise from oxidation of sulfides. Account is then taken of the type of site (natural soil or brownfield), the mobility of the groundwater (static or mobile) and its pH. This leads to the aggressive chemical environment for concrete (ACEC-class) – Table A.2 of BS 8500-1.

The ACEC-class is then considered together with the thickness of the concrete section , the hydraulic gradient due to groundwater (difference in hydrostatic head in metres divided by section thickness in metres) and the intended working life of the structure (at least 50 or at least 100 years).This leads to the DC-class and the number of additional protective measures (APM) required (Table A.9 of BS 8500-1). The additional protective measures are listed in Table A.10 of BS 8500-1.

For each DC-class, options for concrete quality are given (Table A.11 of BS 8500-1). These options allow for the cement or combination type.

The required additional protective measures are selected and the DC-class is specified to the concrete producer. Note that the selection of APM 1 (enhanced concrete quality) and/or the application of the footnotes to Table A.9 can lead to a change in DC-class and it is the **final** DC-class that must be specified.

In practice, the designer may specify to the Contractor the DC-class, the number of APMs and any requirement for specific APMs. The Contractor will then make the choice of the APMs to be applied.

Where there is combined exposure, it is advisable to start with the selection of the appropriate DC-class. Where the limiting values given in Table A.11 of BS 8500-1 are insufficient to meet the recommendations for the other exposure classes, another DC-class should be selected that will meet the recommendations. The specification should include the strength class recommended for the other exposure classes or, if it is more onerous, the minimum required strength class for structural purposes.

Table A.12 of BS 8500-1 gives the limiting values of cement composition for chemical attack in unreinforced concrete in contact with sea water.

(12/14) **Design of concrete for piles**

(ii) (12/14) Specification of concrete for piles should take full account of ground assessment including presence of a high ACEC-class, particularly so if required for high performance structures in which the piles are required to resist tension forces or horizontal loads which create bending moments. In adverse situations the design of the piles must be appraised, and additional precautionary measures such as the use of sleeving considered.

In general, precast and in-situ concrete piles through natural undisturbed unweathered sulfide/sulfate-bearing ground appear to carry little risk of deterioration by sulfate attack. An exception may be cases where the unweathered ground has seepage paths through discontinuities or more permeable zones and there is a flow of groundwater through these which has a high concentration of sulfate derived from a source such as the gypsum present in Mercia Mudstone.

In the case of concrete piles in contact with well-weathered sulfate-bearing clay (such clay is generally free from sulfides such as pyrite), the outer surface should be regarded as at some risk of sulfate attack particularly if ground conditions are wet. The concrete design should be based on the results of a thorough ground appraisal that determines sulfate concentrations at appropriately close vertical intervals (say 1 metre apart).

In-situ concrete piles through 'made' ground may be especially vulnerable to sulfate attack. Waste materials from mining and industry are often rich in sulfides and sulfates. Also, made ground composed of formerly unweathered pyrite-rich clay may potentially have high sulfate contents due to oxidation and bacterial processes. Thorough ground appraisal is needed prior to concrete design. Appropriate procedures are given in BRE Special Digest SD1 and HD 22 'Managing Geotechnical Risk' (DMRB 4.1.2). Effects on inadequately specified concrete piles could include significant reduction in pile section and corrosion of reinforcement.

(12/14) **Sulfates resulting from sulfides in the ground and drainage considerations**

(iii) (12/14) The risk of deterioration due to sulfate attack, including TSA, is worse where clays or other sulfide bearing materials have been excavated, reworked and replaced adjacent to buried concrete. The rapid oxidation of sulfides, particularly pyrites, in disturbed ground, results in enhanced levels of sulfates in the soil and groundwater.

Careful consideration must be given to the choice of materials surrounding buried concrete. They must be assessed in relation to the presence and source of sulfates, the prevailing groundwater conditions, the provision and location of drainage, the proposed usage of the structure, and coatings and other protective measures to be used. Though there may be benefits in considering the use of non-sulfate/sulfide bearing backfills in proximity to structures, designers would need to assess the potential for sulfate migration from remote sources through the backfill.

Large excavations to deep foundations create sumps around buried concrete. If they are unavoidable then account should be taken of the more aggressive groundwater conditions and steps taken to provide adequate drainage to the backfilled excavation and to prevent groundwater entering from the surrounding area. On no account should such excavations be refilled with clays containing high concentrations of sulfates and sulfides.

Sulfate and/or acid bearing groundwater should be intercepted, if possible, before coming into contact with buried concrete, and backfill must be adequately drained. Structure-specific and carrier drains in proximity to the structure or building foundations should be designed to ensure that they have sufficient capacity and that they can be maintained. Detailing of the design of drainage and its construction should be undertaken with care to avoid accidental discharge of contaminated water into backfill to structures, or onto buried concrete surfaces.

(12/14) **Surface protection and sacrificial layer**

(iv) (12/14) Surface protection or a sacrificial layer is required as an additional protective measure for many of the ACEC-classes in Table A.9 of BS 8500-1.

At present there is little information available on the protection afforded by commercially available coatings and tanking against sulfate attack. Traditional methods of using bitumen emulsion based coatings have not been fully effective in all the cases of TSA investigated so far. However, such coatings, properly applied, appear to offer some measure of additional protection, and are an acceptable additional protective measure.

The main requirements of coatings and tanking are listed below:

- provide an impermeable barrier;
- be resistant to sulfates and other deleterious chemicals;
- have a neutral effect on the concrete substrate;
- be resistant to envisaged mechanical damage;
- be easy to apply correctly;
- have long term durability;
- be cost effective.

Such coatings and tanking must be applied in accordance with the manufacturer's instructions, and the workmanship must be of a high standard to maintain their integrity. Various options for coatings and water resisting barriers are discussed in BS EN 1504.

The use of additional 'sacrificial' concrete can be achieved by providing an additional sacrificial thickness of cover concrete integral with parent concrete or by constructing a separate layer of concrete. Sacrificial concrete layer is one of the additional protective measures given in Table A.10 of BS 8500-1. The quality of such a layer should be at least equal to that of the inner concrete. Although service data are scarce, BRE Special Digest SD1 suggests an additional sacrificial layer of 50 mm thickness. The design of the concrete element would need to be reappraised to reflect the additional concrete and the thickness of the sacrificial layer should be ignored for the purpose of crack width calculation.

It should be noted that the use of a sacrificial layer is not appropriate when the layer has a structural function (e.g. skin friction for piles).

Where TSA is considered possible, the need to exercise good control over the maintenance of the design cover in reinforced concrete construction is emphasised to minimise the risk of, and delay the onset of, reinforcement corrosion.

(12/14) **Options for concrete**

(v) (12/14) Designers should provide sufficient information to allow a contractor and concrete supplier to offer a package of proposals to comply with the recommendations, since it could provide the basis for alternative specifications being offered, that may reduce construction costs. The compiler of the specific appendices and drawings should include sufficient information about the design constraints and ground conditions to allow tenderers a fair opportunity to submit their detailed proposals and price the package. A typical package would consist of a concrete conforming to the requirements of BS 8500-1 including any requirement for additional protective measures. For this purpose contract specific Appendix 17/5 should be completed for each structure or group of structures in respect of buried or partially buried concrete.

(12/14) **Early Thermal Cracking**

12 (12/14) The UK National Annex to BS EN 1992-2 states that account should be taken of the effects of restrained thermal and shrinkage strains in the control of cracking. As explained in PD 6687-2 'Recommendations for the design of structures to BS EN 1992-2', complementary guidance for this purpose is given in CIRIA Report C660 'Early age thermal crack control in concrete'. The application of CIRIA C660 requires certain material and execution parameters to be known (such as cement strength class, placing temperature, formwork type etc.). For elements affected by restrained thermal and shrinkage strains, designers should therefore make realistic assumptions for these parameters and they should be stated in contract specific Appendix 17/1. The designer should, where doing so does not adversely affect construction costs, specify a range of acceptable parameters to avoid over-constraining the Contractor.

NG 1705 (12/14) Concrete – Requirements for Designed Concrete

(12/14) **Conformity Criteria**

1 (12/14) Conformity criteria for concrete are given in Clause 8 of BS EN 206-1 and in Clause 12 of BS 8500-2.

(12/14) **Suitability of Proposed Constituent Material Proportions**

2 (12/14) Initial tests should establish a concrete that satisfies all specified requirements for fresh and hardened concrete. Where the specifier or producer can demonstrate an adequate design, based on data from previous tests or long-term experience, this may be considered as an alternative to initial tests. Details of initial testing are given in Annex A of BS EN 206-1.

NG 1706 (12/14) Concrete – Production

(12/14) **General**

1 (12/14) BS EN 206-1 contains detailed provisions for production control. It requires the concrete producer to have a documented production control system and it sets out a list of general requirements, followed by procedures that amplify some aspects of these general requirements. These procedures are allowed to be varied to take account of:

- the kind and size of the production;
- the works;
- the particular equipment being used;
- procedures and rules in use at the place of production;
- the use of the concrete.

What is not specifically stated, but is understood, is that any alternative procedure should achieve effective control of that aspect of production and be documented.

In BS EN 206-1, inspection and certification of the production control by approved inspection and certification bodies is recommended. Attention is drawn to the requirement, in Clause 104, for third party product certification scheme for ready mixed concrete, see Appendix B.

(12/14) **Consistence At Delivery**

2 (12/14) The addition of extra water to a designed concrete will not only increase the slump, but will also increase the shrinkage potential and permeability of the hardened concrete. The extra water will also reduce the final compressive strength of the concrete and its durability.

If more water or admixtures are added to the concrete in a truck mixer on site than is permitted by the Specification, the concrete batch or load should be recorded as "non-conforming" on the delivery ticket. The party who authorized this addition is responsible for the consequences and this party should be recorded on the delivery ticket. 'Non-conforming' concrete should not be included in the permanent works.

(12/14) **Self-Compacting Concrete (SCC)**

3 (12/14) The use of self-compacting concrete is not covered by the Specification. When the use of SCC is proposed through the Overseeing Organisation's Departure processes, appropriate amendments to the Specification clauses dealing with quality control, materials, testing and construction requirements would need to be made, with reference to BS EN 206-9. In particular, attention should be given to the type and class of consistence testing proposed (such as slump flow, viscosity, passing ability and resistance to segregation), the consistence retention time and limitation of admixture dosage rates, both at the batching plant and at the point of delivery. It may be necessary to undertake trial panels to ensure that the specified concrete finishes are achieved and that any necessary controls over the method and rate of placement of SCC can be assessed and instigated.

NG 1707 (12/14) Concrete – Conformity and Identity Testing

(12/14) **General**

1 (12/14) Acceptance testing and contract compliance testing as described in Clauses 104 and 105 should be scheduled by the compiler in contract specific Appendices 1/5 and 1/6. Guidance for this is given in Clauses NG 104 and NG 105.

(12/14) **Conformity**

2 (12/14) BS EN 206-1 requires the concrete producer to determine conformity. Where the producer detects non-conformity, this non-conformity has to be declared to the relevant specifiers and users. Some independent re-assurance that this has been done as required is one of the strongest reasons why concrete should be subject to product certification, see sub-Clause NG 1706.1. The conformity test results and associated analysis should be provided by the concrete producer at least every 3 months.

(12/14) **Non-conformity**

3 (12/14) The action to be taken in respect of the concrete that is represented by the test results that fail to meet the requirements of BS EN 206-1 may range from qualified acceptance in less severe cases to rejection and removal in the most severe cases. In determining the action to be taken, due regard should be given to the technical consequences of the kind and degree of non-compliance, and to the economic consequences of alternative remedial measures either to replace the substandard concrete or to ensure the integrity of any structure in which the concrete has been placed.

In estimating the concrete quality and in determining the action to be taken when the tests indicate non-compliance, the following should be established wherever possible:

(a) the validity of the test results, and confirmation that specimen sampling and testing have been carried out in accordance with the appropriate parts of BS EN 12350 and BS EN 12390;

(b) the constituent materials proportions actually used in the concrete under investigation;

(c) the actual section of the structure represented by the test cubes;

(d) the possible influence of any reduction in concrete quality on the strength and durability of this section of the structure.

In the case of non-compliance, the onus is on the Contractor to demonstrate acceptability to the Overseeing Organisation, and additional tests on the hardened concrete in the structure may be necessary to confirm its integrity or otherwise, performed in accordance with BS EN 1504, BS EN 13791 and BS 6089 'Assessment of in situ strength in structures and precast concrete components – Complementary guidance to that given in BS EN 13791'. Additional guidance is provided in Clause NG 1727.

(12/14) **Identity Testing**

4 (i) (12/14) The specifier or user of the concrete has the right to check the concrete supplied to them. This does not form part of conformity testing, but the producer may opt to use such data in the assessment of conformity. Such testing is called "identity testing", not "acceptance testing" or "contract compliance testing" although in reality its purpose is to decide if a particular batch or batches are in compliance with the Specification and acceptable to the specifier or user.

(ii) (12/14) Identity testing identifies with a high level of probability whether a particular batch or batches come from a conforming population. BS EN 206-1, Annex B and BS 8500-1, Annex B provide rules for the assessment of strength for one or more batches of concrete.

(iii) (12/14) BS 8500-1 gives identity test criteria for slump, flow, air content and density of single batches of concrete. Such testing will determine if the particular batch is accepted or rejected.

(iv) (12/14) Neither BS EN 206-1 nor BS 8500 addresses the situation where the results of identity testing are not in agreement with the results of conformity testing. In this situation the contract parties need to work together to resolve any dispute.

(v) (12/14) The compiler should schedule identity testing in contract specific Appendix 1/5 and/or 1/6 in accordance with Clause 105.

(12/14) **Identity Testing Rates**

5 (12/14) The need for identity testing and the rate of testing should be matched to the use of the concrete. Low strength class concrete usage and concrete used in less critical structural elements usually will not require identity testing to be undertaken, unless there is a specific cause for doubt over quality. High strength class concrete and concrete used in structurally critical elements will usually require identity testing, to confirm that the supplied concrete conforms to the required characteristics of the specified concrete.

6 (12/14) Where identity testing is not restricted to cases of doubt or random spot checks, the type of tests to be carried out, the volume of concrete in the assessment and the number of tests to be carried out on this volume of concrete should be described in contract specific Appendix 17/4.

7 (12/14) Typical rates of sampling for identity testing are given in Table NG 17/2 below, but not less than one sample should be taken on each day for each concrete class used.

(12/14) **TABLE NG 17/2: Typical Rates of Sampling and Testing**

Use of concrete	**Sample from one batch selected randomly to represent an average volume of not more than the lesser of (assumes batches of 6 m^3):**
Prestressed concrete	12 m^3 or 2 batches
Reinforced concrete	From 24 m^3 or 4 batches to 96 m^3 or 16 batches depending on application
Mass concrete	From 50 m^3 or 50 batches whichever represents the lesser volume

8 (12/14) Higher rates of sampling and testing may be required at the start of work or if the level of quality is in doubt; conversely, rates may be reduced when high quality has been established.

9 (12/14) For special reinforced concrete such as end blocks, half-joints or other highly stressed areas the rates of sampling for prestressed concrete may be considered more appropriate.

(12/14) **Air Content of Fresh Concrete**

10 (12/14) It should be noted that the method of measuring air content described in BS EN 12350-7 is not applicable to concrete made with lightweight aggregate, and reference should be made to Annex B of BS 8500-1 for lightweight concrete.

(12/14) **Additional Tests on Concrete for Special Purposes**

11 (12/14) Additional cubes may be required for various purposes. These should be made and tested in accordance with BS EN 12390, but the methods of sampling and the conditions under which the cubes are stored should be varied according to the purpose for which they are required. For determining the cube strength of prestressed concrete before transfer or of concrete in a member before striking formwork or removing cold weather protection, sampling should preferably be at the point of placing, and the cubes should be stored as far as possible under the same conditions as the concrete in the members. The extra cubes should be identified at the time of making and should not be used for the normal conformity or identity testing procedures.

NG 1708 (12/14) Concrete – Surface Finish

(12/14) **General**

1 (12/14) The type of surface finish required depends on the nature of the member, its final position in the structure, and whether or not it is to receive an applied finish. The appropriate finish, which may vary from face to face, should be carefully chosen and clearly specified.

Wherever possible, samples of surfaces of adequate size (preferably incorporating a horizontal and vertical joint and reinforcement representative of heavily congested zones of reinforcement) should be agreed before work commences. All the factors affecting the quality of the surface finish from formwork should be carefully studied. For detailed descriptions of these factors and their interrelationship, attention is directed to the Concrete Society Publication 'Concrete on Site 8 – Making good and finishing'.

Texture, colour and durability are affected by curing (see NG 1710.5). Where appearance is important, curing methods and conditions including the time of removal of formwork require careful consideration. Components that are intended to have the same surface finish should receive the same treatment.

Annex F of BS EN 13670 gives some guidance on the requirements for surface finish, and typical uses of four finish types (basic, ordinary, plain and special) are given in Table F.4. However, for highway structures, the provisions and class types given in this Specification should be used.

(12/14) **Control of Colour**

2 (12/14) Where uniformity of colour is important, all materials should be obtained from single consistent sources. In formwork the replacement of individual plywood sheets or sections of timber in large panels should be avoided. Colour can be affected by curing.

(12/14) **Release Agents**

3 (12/14) Release agents for formwork should be carefully chosen for the particular conditions they are required to fulfill. Where the surface is to receive an applied finish, or it is to be impregnated, care should be taken to ensure the compatibility of the release agent with the subsequent treatment process, for example no deleterious residue should be left.

(12/14) **Surface Finishes for Concrete**

4 (i) (12/14) The class of finish should be shown on the drawings. Class F1 finish should be specified for unexposed formed surfaces and Class F2 finish normally for exposed surfaces. F3 finish is very costly and should only be used for small areas. F4 is appropriate where large areas are required to have a first class appearance. Although metal parts should never be permanently embedded within the cover depth from the surface of the concrete, internal ties can be used in ways which will not detract from the appearance. For instance, if made coincident with certain types of surface features (eg vertical grooves formed to break up large areas or features which create shadow effects) the holes are practically indiscernible and an economical design of formwork ensues. The designer is urged to be flexible in his requirements for surface features bearing such facts in mind. For Class F3 and F4 finishes, it is recommended that trial panels should be made. Class F5 finish is primarily intended for precast pretensioned beams. The position of the exposed surfaces in the finished structure should be taken into account in determining the extent of making good. In cases where beams are of the same design it is possible, within practical limits, to minimise the extent of making good by selecting beams with the best surface finish for positions of maximum exposure.

There have been some difficulties over what constitutes an acceptable finish in precast prestressed beams. Therefore before an order is placed it is advisable to inspect typical beams from a beam manufacturer's works before deciding whether a finish is required which is different from that normally produced. Further guidance on the finishes for precast concrete is given in PD CEN/TR 15739 'Precast Concrete Products – Concrete Finishes – Identification'.

ii) (12/14) Reference panels have been produced for each region of UK, demonstrating typical F2 and F4 finishes produced in that region, using local materials. They are not intended to show the best possible finish and accordingly accommodate a range of typical blemishes and imperfections. Their purpose is to stimulate debate between parties on each contract when agreement cannot be reached on the standard of finish required and an acceptable level of imperfections. It is recommended that these panels be viewed, if appropriate, at pre-contract stage.

Location and viewing arrangements of the panels are given below and at the CBDG website (www.cbdg.org.uk):

London South (External Site)

University of Greenwich
The Medway School of Engineering
Medway University Campus
Chatham Maritime
Kent
ME4 4TB

South West England (External Site)

University of the West of England
Department of Built Environment
Coldharbour Lane
Bristol
BS16 1QY

Central England (External Site)

Peri Ltd
Market Harborough Road
Clifton upon Dunsmore
Rugby
CV23 0AN

(iii) (12/14) Class U2 finish should normally be specified for exposed concrete; Class U3 being reserved for positions where the surface is required to be especially smooth for functional or aesthetic reasons; Class U4 finish is to be used for bridge decks that are to receive waterproofing systems; Class U5 finish is reserved for footbridge surfaces that are to receive either separate or combined systems, or coatings of waterproofing and surfacing materials. The method adopted for finishing a surface which is to receive deck waterproofing should be such that a layer of laitance is not left on the surface nor the coarse aggregate exposed.

(iv) (12/14) Other classes of finish should be fully specified and scheduled in contract specific Appendix 17/3 and should, if possible, be related to samples that are readily available for comparison. Included under this heading is any finish that requires the coarse aggregate to be permanently exposed, the use of special forms or linings, the use of a different concrete mix near the surface, grinding, bush-hammering or other treatment.

(12/14) **Protection**

5 (12/14) High quality surface finishes are susceptible to subsequent damage, and special protection may have to be provided in vulnerable areas.

NG 1709 (12/14) Not Used

NG 1710 (12/14) Concrete – Construction General

(12/14) **Construction Joints**

1 (12/14) The number of construction joints should be kept as few as possible consistent with reasonable precautions against shrinkage and early thermal movement. Concreting should be carried out continuously up to construction joints.

Where it is necessary to introduce construction joints, careful consideration should be given to their exact location, which should be shown either on the drawings or determined by the Contractor in accordance with the specified criteria. Construction joints should be at right angles to the general direction of the member and should take due account of shear and other stresses.

Where non-prepared joints are to be used that meet the interface shear requirements of 6.2.5 of BS EN 1992-1-1, they should be specified (in contract specific Appendix 17/4) or approved by the designer.

Laitance is the dusty milk cement compound which can generally be removed after the concrete has hardened using a stiff brush.

When open mesh permanent formwork is proposed, its suitability should be supported by sufficient information about its stiffness, strength, method of use and performance.

The use of retarding agents painted onto formwork should be discouraged because they tend to migrate into the concrete under the action of vibration.

Concrete should not be allowed to run to a feather edge and vertical joints should be formed against a stop end. The top surface of a layer of concrete should be level and reasonably flat unless design requirements are otherwise. Joint lines should be so arranged that they coincide with features of the finished work.

If a kicker (i.e. a starter stub) is used, it should be at least 70 mm high and carefully constructed. Where possible, the formwork should be designed to facilitate the preparation of the joint surface, as the optimum time for treatment is usually a few hours after placing.

Particular care should be taken in the placing of the new concrete close to the joint. This concrete should be particularly well compacted.

(12/14) **Falsework and Formwork**

2 (12/14) All falsework and permanent or temporary formwork should be adequate for the proper construction of the works. Appropriate guidance on falsework and formwork is given in BS 5975 'Code of practice for temporary works procedures and the permissible stress design of falsework', BS EN 12812 'Falsework – Performance requirements and general design' and Concrete Society Publications CS 030 ' Formwork: a guide to good practice', CS 123 'Checklist for Erecting and Dismantling Falsework', CS 140 'Guide to flat slab falsework and formwork' and CS 144 ' Checklist for Assembly, Use and Striking of Formwork'.

Before any falsework or formwork is constructed, the Contractor should prepare detail drawings, including details of external vibrators where proposed and the depth of lifts to be concreted where appropriate. The drawings should be supported by calculations which show the adequacy of the proposals.

Requirements for permanent formwork, for either internal or external use, should be described in contract specific Appendix 17/4; due regard being given to the conditions to which it is likely to be exposed and to its function in the structure. The material selected for external use must be durable, particularly at exposed edges or joints.

Requirements for special formwork, like for example controlled permeability formwork (CPF), should be described in contract specific Appendix 17/4. Information on the use of CPF can be found in the CBDG Current Practice Sheet No. 10 ‘Controlled Permeability Formwork’.

(12/14) **Transporting, Placing and Compacting**

3 (12/14) Concrete should be transported from the mixer to the formwork as rapidly as practicable by methods that will prevent the segregation or loss of any of the ingredients and maintain the required workability. It should be deposited as near as practicable to its final position to avoid rehandling.

All placing and compacting should be carried out under the direct supervision of a competent member of the Contractor’s (or manufacturer’s) staff. Concrete should normally be placed and compacted soon after mixing, but short delays in placing may be permitted provided that the concrete can still be placed and effectively compacted without the addition of further water.

A cohesive concrete mix that does not segregate may be allowed to fall freely provided that special care is taken to avoid displacement of reinforcement or movement of formwork, and damage to faces of formwork. In massive sections it is necessary to consider the effect of lift height on the temperature rise due to the heat of hydration.

When pumping lightweight aggregate concrete, appropriate precautions should be taken. The aggregate should be pre-soaked, as pressure during pumping will drive water into the aggregate pores resulting in loss of slump. Adjustment to slump, air content and aggregate content may be necessary to ensure adequate pump ability. Water squeezed in and out of the aggregate during pumping may result in the weakening of the transition zone between the aggregates and the cement paste. Evidence from previous trials using the same pumping system and procedure proposed should demonstrate that there is no significant adverse effect on the strength of the hardened lightweight aggregate concrete.

Concrete should be thoroughly compacted by vibration, pressure, shock or other means during the operation of placing to produce a dense mass having the required surface finish when the formwork is removed.

Whenever vibration has to be applied externally, the design of formwork and disposition of vibrators should receive special consideration to ensure efficient compaction and to avoid surface blemishes.

The mix should be such that there will not be excess water on the top surface on completion of compaction. It may be necessary to reduce the water content of batches at the top of deep lifts to compensate for water gain from the lower levels, but this can be avoided by designing the mix, checking with preliminary trials and accurately controlling the mix proportions throughout the work.

Spillages of concrete onto other parts of the permanent structure, e.g. structural steelwork, should be removed immediately after they occur to avoid damage to finishes.

Additional guidance is given in the Concrete Society Publication CS164 – Good concrete guide 8’ Concrete practice – Guidance on the practical aspects of concreting’. Guidance for slipforming is given in the Concrete Society Publication CS 162 – Good concrete guide 6 ‘Slipforming of vertical structures’.

(12/14) **Removal of Formwork and Falsework**

4 (i) (12/14) General. The time at which formwork is removed is influenced by the following factors:

(a) concrete strength;

(b) stresses in the concrete at any stage in the construction period, which in the case of precast units includes the stresses induced by disturbance at the casting position and subsequent handling;

(c) curing (see NG 1710.5);

(d) subsequent surface treatment requirements;

(e) presence of re-entrant angles requiring formwork to be removed as soon as possible after concrete has set to avoid shrinkage cracks;

(f) requirements of any deflection profile.

The falsework and formwork should be removed slowly, as the sudden removal of supports (e.g. wedges or props) is equivalent to a shock load on the partly hardened concrete.

Special care should be taken when formwork is struck to avoid the risk of breaking off the edge of concrete adjacent to any projecting reinforcement.

(ii) (12/14) Time before removal for cast in situ concrete.

Field conditions for control cubes may be simulated by temperature matching curing or other methods. In the absence of control cubes, reference should be made to specialist literature, e.g. CIRIA Report 136 "Formwork Striking Times – Criteria, Prediction and Methods of Assessment" for appropriate guidance.

The periods given in Table 17/2 of the Specification are not intended to apply where accelerated curing or slip forms are used. Where it is not practicable to ascertain the surface temperature of concrete, air temperatures may be used though these are less precise. In cold weather the period should be increased according to the reduced maturity. For example, for soffit formwork it would be appropriate to increase the value by half a day for each day on which the concrete temperature was between 2°C and 7°C, and by a whole day for each day on which the concrete temperature was below 2°C.

When formwork to vertical surfaces such as beam sides, walls and columns is removed in less than 12 hours, care should be exercised to avoid damage to the concrete, especially to arrises and features. The provision of suitable curing methods should immediately follow the removal of the vertical formwork at such early ages, and the concrete should be protected from low or high temperatures by means of suitable insulation (see NG 1710.5).

(12/14) **Curing**

5 (i) (12/14) General. The method of curing and its duration should be such that the concrete will have satisfactory durability and strength and the member will suffer a minimum of distortion, be free from excessive efflorescence and undue cracking.

The duration of applied curing shall be determined by the development of satisfactory concrete properties in the surface zone. These required properties are indicated by curing classes, as given in BS EN 13670 Table 4. The curing classes are defined in terms of the percentage of the specified characteristic 28 day compressive strength that must be achieved by the surface concrete. Methods of estimating the development of concrete properties in the surface zone are given in Annex F of BS EN 13670.

Curing class 3 is consistent with previous practice adopted on highway structures. For curing class 3 curing should be continued until the surface strength has reached 50% of the specified characteristic 28 day compressive strength. Table F.2 of EN 13670 which gives minimum curing periods for curing class 3 may be used. To use Table F.2 information on concrete strength development will need to be obtained from the producer, in accordance with Clause 7.2 of BS EN 206-1 and Clause 7.1 of BS 8500-2.

To meet the requirements of BS EN 13670 and the Specification it may be necessary to insulate the concrete so that it is maintained at a suitable temperature, or so that the rates of evaporation of water from the surfaces are kept to appropriate values, or both. Different curing or drying treatments are appropriate to different members and products. Where necessary, special care should be taken to ensure that similar components are cured as far as possible under the same conditions.

Curing usually consists of maintaining the formwork in place and covering the concrete with a vapour barrier material such as polythene sheet or a curing compound or with an absorbent material that is kept damp for a period of time. Where formwork is removed before curing is complete some other form of protection should be used to maintain a curing environment.

Where structural members are of considerable depth or bulk or have an unusually high proportion of cement or are precast units subjected to special or accelerated curing methods, the method of curing should be specified in detail. Some special cases are cited as examples in NG 1710.5(iii).

The higher the rate of development of strength in concrete, the greater the need to prevent excessive differences in temperature within the member and too rapid a loss of moisture from the surface. Alternate wetting and drying should be avoided, especially in the form of cold water applied to hot concrete surfaces. In order to avoid surface cracking, cold water should not be applied to relatively massive members immediately after striking the formwork while the concrete is still hot.

(ii) (12/14) Accelerated curing. Accelerated curing (which includes steam curing) consists of curing the concrete in an artificially controlled environment, in which the humidity and the rate of temperature rise and fall are controlled, to speed up the rate of increase in strength.

(iii) (12/14) Additional Considerations.

The principal reasons and recommendations for curing concrete are given in (i) and (ii) above. The following parts of this sub-Clause are intended to amplify the factors that should be considered. The recommendations are based on the assumption that the concrete temperature during the curing period will not fall below 2°C. Particular precautions to be taken when concreting at low air temperatures are given in NG 1710.6.

(a) Strength of concrete. The effect of admixtures on curing should be considered. The higher the rate of development of strength of the concrete (and hence of heat of hydration of the cement), the more care should be taken during the early period after casting to prevent excessive differences in temperature within the concrete and excessive loss of moisture from the pour. It should be noted that the rate of gain of strength is increased if the temperature of the concrete is raised.

Curing by means of damp absorbent materials is likely to cause a lowering of the temperature of the concrete as a result of the evaporation from the material, and in some circumstances the effect can be significant. The rate of development of strength diminishes as the concrete dries out; hence excessive evaporation of water from all surfaces may need to be prevented.

(b) Distortion and cracking. The concrete should be cured so that internal stresses within the member, whether due to differences in temperature or differences in moisture content within the concrete, are not sufficient to cause distortion or cracking. The disposition of reinforcement will affect the restraint to the strains, and hence it will have an effect on any distortion and cracking.

In assessing the likely temperature variation within the concrete, the following factors apply:

- rate of heat evolution (related to rate of development of strength);
- size and shape of member;
- different insulation values of curing media (e.g. wooden moulds or water spray);
- external temperature.

For example, surface cracking may occur as a result of variation in temperatures due to applying a cold water spray to a relatively massive member immediately after stripping the moulds while the concrete is still hot.

In assessing the likely variation in moisture content within the concrete, the rate of evaporation from unprotected concrete will be higher with atmospheric conditions encouraging evaporation (e.g. low relative humidity, high wind speed, concrete surface hotter than the air), especially if the rate of migration of water through the concrete is greater than the rate of evaporation from the surface. E.G. for:

- members of high surface/volume ratio;
- concrete at early age or lower strength class of concrete.

For example, cracking may occur due to varying shrinkage in members with sudden changes in section that affect the surface/volume ratio appreciably; especially if the more massive section is reinforced and the more slender section is not.

If the shrinkage of units after they are built into the structure is likely to lead to undesirable cracking at the ends of the unit, curing aimed at preventing the loss of water from the unit should be continued no longer than is necessary to obtain the desired durability and strength; thereafter the concrete should be given the maximum opportunity to dry out consistent with the limitation of the variation in moisture content as already outlined.

Further information can be obtained from CIRIA Report C660 'Early-age Thermal Crack Control in Concrete'. Reference should be made to sub-Clause NG 1704.12.

(c) Durability and appearance. As deterioration is most likely to occur as a result of the concrete providing inadequate protection for the reinforcement, or because of frost attacking the surface concrete, all vulnerable surfaces of concrete should be protected against excessive loss of water by evaporation that would result in a weak, porous surface layer.

Where it is important to prevent the formation of efflorescence, especially in cold weather, the atmosphere adjacent to the surface of the concrete should be maintained at a constant relative humidity approaching 100% until removal of formwork. Concrete should be protected from wetting and drying cycles.

(iv) (12/14) Curing liquids, compounds and membranes. Before curing liquids, compounds and membranes are accepted for use on surfaces on which waterproofing systems are to be laid they should be shown to be completely removable by natural or mechanical means. It should be noted that proprietary liquid curing membranes may take a long time to disintegrate and may affect the appearance of permanently visible surfaces as well as the bond of any waterproofing layer.

To achieve optimum breakdown of the membrane the manufacturer's recommendations for prior wetting or dampening of the concrete surfaces and the rate of application of the membrane material should be closely followed.

(12/14) **Cold Weather Work**

6 (i) (12/14) General. Before placing concrete, the formwork, reinforcement, prestressing steel and any surface with which the fresh concrete will be in contact should preferably be at a temperature close to that of the freshly placed concrete. Special care should be taken where small quantities of fresh concrete are placed in contact with larger quantities of previously cast concrete at a lower temperature. Any concrete damaged by frost should be removed from the work.

Concrete temperatures should be measured at the surface at the most unfavourable position.

(ii) (12/14) Concrete Temperature

The raising of the temperature of the concrete may be achieved in a number of ways including the following:

(a) By heating the mixing water and aggregate. If the water is heated above 60°C, it is advisable to mix the water with the aggregate before adding the cement.

(b) By increasing the cement content of the mix or by using a more rapid hardening cement.

(c) By covering the top face of slabs and beams with adequate insulating material.

(d) By providing wind breaks to protect newly placed concrete from cold winds.

(e) By using a heated enclosure, completely surrounding the freshly placed concrete or using heated formwork panels. In either event care should be taken to prevent excessive evaporation of water from the concrete.

(f) By using admixtures that reduce the setting time and/or increase the rate of strength gain, subject to the provisions and limitations of Clauses 1702 to 1706 in using admixtures.

Formwork should be left in place as long as possible to provide thermal insulation; timber formwork provides better insulation than steel. Further guidance on this subject can be obtained from the Concrete Society Publication 'Concrete on Site 11 – Winter Working'.

(12/14) **Hot Weather Work**

7 (12/14) In hot weather, the incidence of cracking and loss of workability may be reduced if measures are taken to cool the constituent materials. Aggregates can be kept cool by protecting them from direct sunlight and by spraying with water, making due allowance for the moisture content of the mix. Water pipes, particularly if long, should preferably be shaded and if possible insulated.

Additional measures may include the use of a cement or combination with a low heat evolution, the use of admixtures to retard the hydration and/or increase the initial workability, subject to the provisions and limitations of Clauses 1702 to 1706 in using admixtures.

(12/14) **Precast Concrete Construction**

8 (i) (12/14) General

Factory produced or site manufactured precast concrete elements are defined by BS EN 13670 as ‘precast products’ if they are manufactured and designed in accordance with a relevant European Product Standard or with BS EN 13369 ‘Common rules for precast concrete products’.

BS EN 13369 defines the common rules for precast products and is complemented by a series of type-specific Product Standards, issued by the Technical Committee CEN/TC 229 ‘Precast concrete products’. The most relevant of these for highway structures is BS EN 15050 ‘Bridge elements’, which covers bridge deck elements. Other Product Standards relevant for highway structures include, but are not necessarily limited to, BS EN 12794 ‘Foundation piles’, BS EN 14844 ‘Box culverts’, BS EN 15258 ‘Retaining wall elements’ and BS EN 12843 ‘Masts and poles’.

The scope of BS EN 13369 and the Product Standards is wide and it is therefore expected that precast concrete elements for use in highway structures would be ‘precast products’ and would therefore need to comply with the relevant Product Standard and/or BS EN 13369.

It should be noted that precast elements to be used in the UK, even if manufactured abroad, have to be designed in accordance with the provisions of the UK National Annexes to the Eurocodes and associated implementation documents of the Overseeing Organisation.

(ii) (12/14) Manufacture of precast products

Where a precast concrete element conforms to a harmonised European Product Standard, has a Declaration of Performance (DoP) and CE marking in accordance with the Construction Products Regulation (CPR) and the declared performance on the DoP meets the requirements of the specification for the works, then in accordance with the CPR there is a presumption that the product complies with those specification requirements covered by the DoP.

A number of options with respect to the minimum set of information to be provided with the CE marking and labelling are given in Annex ZA of the Product Standards. Generally three methods are given which include reference to technical information, technical documentation or design specifications. Precast concrete products for use on highway structures are generally based on a given design specification that contains all the technical data necessary to fully specify the product, normally in the form of detailed drawings giving the information necessary to manufacture the product without the need for further calculations. In BS EN 15050, this corresponds to method of Clause ZA.3.4. The compiler should include which method is required for CE marking and labelling for each item for each relevant Product Standard in contract specific Appendix 17/7.

Contract specific Appendix 17/7 contains references to all technical data prepared by the designer. In some cases, the technical data required for manufacture may comprise the design parameters which the manufacturer should use to design the product (for example, participating permanent formwork comprising precast concrete units incorporating a welded lattice, referred to as floor plates in Annex C of BS EN 15050). Therefore, in the case of a product where all of part of the design is undertaken by the manufacturer, contract specific Appendix 17/7 include reference to technical data containing all the information necessary to design the element, including for example relevant design standards, loading and durability requirements.

(iii) (12/14) Manufacture of precast concrete elements not conforming to any Product Standard or to BS EN 13369

Units may be measured at any convenient time but not less than 7 days after casting, provided that the alternative time proposed by the Contractor is supported by calculations to demonstrate the dimensions predicted for 28 ± 2 days.

(iv) (12/14) Requirements for all precast elements (including precast products)

(a) General. The designer should show on the drawings the type of preparation of the surfaces of concrete elements which will subsequently receive in situ concrete. The surface roughness strongly influences the interface shear between the precast element and in situ concrete.

The methods of surface preparation described in Clause 1710.8(iv)(a) are well established and are able to achieve the 'Rough' surface classification described in Clause 6.2.5(2) of BS EN 1992-1-1. Where alternative methods of surface preparation are proposed by the manufacturer these should be supported by tests or other evidence that the relevant surface classification is achieved by the proposed method.

To benefit from manufacturer's normal practice, it is recommended that, for factory made pretensioned beams, the designer should be prepared to accept alternative types and positions of tendons and stipulate the criteria for acceptance of alternatives including maximum assumed losses. Where the size and position of the tendons is shown on the drawings, the words "or equivalent" should be added and the force before transfer and its eccentricity should be given.

(b) Handling. Precast units should resist, without permanent damage, all stresses induced by handling and transport. The minimum age for handling and transport should be related to the concrete strength, the type of unit and other relevant factors.

The designer should specify all constraints on the position of lifting and supporting points, the method of lifting, the type of equipment, the minimum age for handling and transport to be used. It should be noted that, because of the layout of trucks, it may not always be possible to support precast units beneath lifting points during transport. The manufacturer is generally required to provide a 'lifting scheme' in accordance with Clause 9.4.2 of BS EN 13670, and where alternative positions of lifting or support are proposed, the suitability of these shall be demonstrated by calculations to the satisfaction of the designer.

Requirements for the preparation of a lifting scheme and the constraints on handling and transportation to be considered are to be provided in contract specific Appendix 17/7.

Care should be taken to ensure that constraints on lifting provide for lifting details that are practicable and can be used safely, and in a way that no damage results from the lifting equipment.

During transport, consideration should be given to distortion of the transporting vehicles, centrifugal force due to cornering, the possibility of damage due to chafing and oscillation (a slim element may flex vertically or horizontally sufficiently to cause damage).

Further guidance on lifting and handling for precast concrete is given in PD CEN/TR 15728 'Design and Use of Inserts for Lifting and Handling of Precast Concrete Elements'.

(c) Storage. The designer should in all cases specify the constraints on the points of support during storage and limits on the stacking of elements. These should be chosen to prevent unacceptable permanent distortion and lack of fit of the units. In order to minimise the stresses induced, supporting arrangements that permit only small settlements or deflections are to be preferred.

The accumulation of trapped water and rubbish in the units should be prevented. The freezing of trapped water can cause severe damage. Where necessary, precautions should be taken to avoid rust stains from projecting reinforcement and to minimise efflorescence.

(d) Protection. The degree and extent of the protection to be provided should be sufficient for the surface finish and profile being protected, bearing in mind its position and importance. This is particularly important in the case of permanently exposed concrete surfaces, especially arrises and decorative features. The protection can be provided by timber strips, hessian, etc, but should not be such as will damage, mark or otherwise disfigure the concrete.

(e) Placing and adjustment. Where the method of placing and adjustment is part of the design, it should be stated in contract specific Appendix 17/7. The requirements of BS EN 13670 with regard to precast concrete elements shall be complied with. Attention is drawn to the requirements for the erection specification given in Clauses 9.5 and 9.6 of BS EN 13670. Further guidance on the information the erection specification should include is given in BS EN 13369.

(f) Requirements for placing and adjustment of composite slab bridges. In order to ensure compliance with sub-Clause 1710.8(iv)(f) it may be advisable to have the camber of precast beams measured at the factory so that they can be placed in the correct order.

The object of preventing lateral movement of precast beams in composite slab bridges is to prevent differential movement between beams, which may occur if the concrete is placed in longitudinal strips. This is particularly important when the beams are supported on flexible bearings.

(g) Jointing and completion works. The precast units should be inspected to ensure that the design requirements of the structural connection can be met. The precast units should be free from irregularities which may cause damaging stress concentrations.

When reliance is placed on bond between the precast and in situ concretes, the contact surface of the precast unit should have been prepared in accordance with sub-Clause 1710.8(iv)(a).

When joints between units, particularly the horizontal joints between successive vertical lifts, are load-bearing and are to be packed with mortar or concrete, tests should be carried out to prove that the material is suitable for the purpose and that the proposed method of filling results in a solid joint (for bedding mortar see Clause 2601).

Where epoxy resin bonding agents for segmental deck construction are to be used, the compiler should prepare additional specification requirements based on a review of permissible options. A set of performance requirements should be stated in contract specific Appendix 17/7, together with the requirement that installation is to be in accordance with the manufacturer's recommendations.

Careful consideration should be given to the proposed methods for removing levelling devices such as nuts and wedges.

NG 1711 (12/14) Concrete – Grouting and Duct Systems for Post-tensioned Tendons

(12/14) General

1 (12/14) General guidance and recommendations for post-tensioned structures are given in the Concrete Society Technical Report TR 72 'Durable post-tensioned concrete structures', which is a revised and updated version of the TR 47 2nd edition referred to in the previous version of the Specification. The report implements the provisions of the BS EN 445, BS EN 446 and BS EN 447 for the specification of grouts for prestressing tendons and adds a series of recommendations which are incorporated in the present Specification in the appropriate sub-Clauses.

The Specification states that the contract specific Appendix 17/6 will contain the required intended use category for the prestressing system. The compiler must therefore ensure that the intended use of the prestressing system appropriate to the design is given with the required performance of the system.

It should be noted that Clause 7.2 of BS EN 13670 requires post-tensioning systems to hold an ETA. An ETA is a 'European Technical Assessment' under the Construction Products Regulation (CPR) and was previously known as a 'European Technical Approval' under the Construction Products Directive (CPD). Harmonised technical specifications, i.e. 'European Assessment Documents (EADs)' under the CPR, previously known as 'European Technical Approval Guidelines' (ETAGs) under the CPD, are the basis for issuing ETAs for products not covered by harmonised European product standards (hENs).

The Specification allows for the Overseeing Organisation to call for full-scale trials to be carried out to demonstrate that the grouting will provide adequate protection to the tendons. This requirement should be specified in contract specific Appendix 17/6 and fully detailed on the contract drawing, including trial element size, concrete strength class, cover to reinforcement and tendons, reinforcement and tendon details, together with requirements for testing and investigation. The designer should recognise that the purpose of the trial is to test the Contractor's systems and methods and personnel proposed for the permanent works and should incorporate any particular requirements pertaining to the construction sequence and duct configurations. Requirements for subsequent disposal of the trial element should be specified.

Feedback from previous contracts has shown that there are very significant benefits for all parties in undertaking a full-scale trial. In the circumstances, it is advocated in all but very minor post-tensioning and grouting operations where proven evidence of satisfactory grouting from a significant number of previous trials using the same procedures, equipment and pre-bagged grouts exists. Testing requirements to prove protection against ingress of contaminants are given in section 8 of the Concrete Society TR 72.

The trials should be carried out well in advance of the planned need for use of post-tensioning in the permanent works (56 days is the default period in the Specification). In particular, any proposals for untried systems should be given due time for acceptance. Acceptance criteria for the trials should be specified and agreed with the Overseeing Organisation. Successful completion of the trials and materials tests will allow commencement of the grouting in the permanent works.

Grouting techniques such as vacuum grouting and post-injection regrouting are available from some suppliers and can be considered to be demonstrated as suitable in trials.

(12/14) **Grout Materials, Batching and Mixing**

2 (12/14) The grout may be supplied as a proprietary manufactured pre-bagged material, to which water must be added, or as a designed site batched blend of cement, admixtures and water. Both materials have identical performance requirements. Irrespective of whether full-scale grouting trials have been specified, performance of the grout will in all cases be assured by suitability testing, performed in accordance with BS EN 446. All highway structures are classed under Execution Class 3 in accordance with Clause 1701.4.

The use of pre-bagged factory-formulated grouts requiring only the addition of water on site, which have consistent and reliable properties, is preferred and strongly recommended over the use of site-batched grouts, the latter being often adopted for large-scale works. However, where bagged cement is used in site-batched grout variations in age, chemical composition, fineness and temperature can have significant effects on the performance of the grout. Consequently, tight site controls and accurate batching are required to ensure the uniformity and consistency of the resultant grout. The water/cement ratio should normally be in the range 0.30-0.40 in order to achieve the performance requirements.

(12/14) **Admixtures**

Expanding grout admixtures are supplied as powders which react with grout constituents to expand to ensure that there is no overall decrease in the volume of grout at the end of the hardening period. Non-expanding grout admixtures are supplied in liquid or powder form.

Both types of grout admixture may also permit a reduction in water/cement ratio, improve fluidity, reduce bleeding or retard the set of the grout.

(12/14) **Properties, Performance and Testing of Grout**

3 (12/14) BS EN 447 defines the properties of grouts, their performance requirements and the extent of testing for the evaluation of conformity by the manufacturer. Test methods are described in BS EN 445. Section 6 of BS EN 446 defines the extent of the suitability testing, to be performed in all cases (sub-Clause 1711.1).

The requirements for testing grout during grouting are given in Table 3 of BS EN 446, and are described as inspection requirements during grouting. These correspond to the acceptance testing described in the previous version of the Specification.

The fluidity of the grout during injection should be sufficiently high for it to be pumped effectively and adequately to fill the duct, but sufficiently low to expel the air and any water in the duct. The time during which fluidity is maintained may need to be more than the minimum of 30 minutes given in BS EN 446 and BS EN 447. A target of 90 minutes is recommended as a sensible upper limit.

The grout should be sufficiently stable to bleed very little, so the materials segregate and settle to a minimal extent. It is recommended that the allowable volume change limits in BS EN 445, 446 and 447 are amended such that the volume change is within the range of -0.5% and 2.0%.

The requirement within BS EN 447 for density tests has been questioned in practice, as there are differences of opinion about its value over and above the fluidity test. It is understood that a correlation between fluidity and density is possible, but that this can vary significantly at different temperatures and further research is needed on the matter. In the meantime, the density test should be carried out as required.

(12/14) **Duct Systems**

4 (12/14) Sub-Clause 1711.4 requires the ducting to form an air and water resistant protective barrier as an additional defence against corrosive contaminants. This follows the philosophy of multi-layer corrosion protection adopted in the Concrete Society Technical Report 72. Polyethylene and polypropylene are suitable materials for ducting but other materials may also be suitable.

The purpose of air testing is to demonstrate, first, that the system provides an adequate degree of resistance to contaminants and, second, that the system is correctly assembled and has no significant leaks. The pressure testing requirements make reference to compliance testing before installation and duct assembly verification testing. It is expected that all currently available systems can pass the latter test, but designers should seek the prestressing supplier's guidance before completing contract specific Appendix 17/6.

There are circumstances where the requirement for a sealed ducting system will be difficult for example in precast segmental construction. The designer should consider the options. Sealing of ducts at joints in precast segmental construction is an issue which remains to be satisfactorily resolved, and consequently such a form of construction using internal grouted tendons is not currently permitted.

(12/14) **Duct Assembly Verification Tests**

The mandatory Duct Assembly Verification Test included in the Specification is intended to demonstrate that the system has been correctly assembled. If the system fails to meet the criteria required by the test, it should be dismantled, any damaged items replaced, and the system reassembled and re-tested. If it still fails to comply, sealing of joints with the addition of a suitable sealant may improve matters. Acceptance would then be subject to the Overseeing Organisation's decision on the results of re-testing.

Appendix A of TR 72 describes additional tests to measure the effectiveness of seal provided by the duct system, which the designer may wish to consider adopting in appropriate circumstances. These methods require further experience and development before adoption as a specification requirement.

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

For external tendons the minimum wall thickness should be 4 mm for durability, or such thicker wall as required to withstand grouting pressures of the particular duct configuration. It is important to anticipate any sagging of the duct due to the weight of grout, particularly for tendons stressed after grouting, and appropriate temporary duct support should be provided during the grouting operation.

Minimum wall thickness of the ducting after tensioning should be considered by the designer and appropriate requirements specified in contract specific Appendix 17/6, taking account of minimum radii of curvature of the tendons which will tend to bite into the duct wall. Type and spacing of duct supports also need careful attention to avoid this. Manufacturers' and suppliers' data should be referred to.

The requirement for bond length is given as 50-100 diameters of the duct in line with the recommendations of the International Federation for Structural Concrete (fib) Technical Report Bulletin No. 7, 'Corrugated plastic ducts for internal bonded post-tensioning'. If the designer wishes to give an alternative, this should be specified in contract specific Appendix 17/6.

(12/14) **Vents**

The internal diameter of vents should be as large as possible but designers should bear in mind the sizes included within available systems. The vents, connections and taps should be sufficiently robust to withstand full grouting pressure.

For most applications a minimum vent height of 500 mm above the highest point on a duct is recommended to help entrapped air and water to escape. For some configurations of tendons this will not be appropriate and the designer should specify an alternative in scheme specific Appendix 17/6.

Some designers and some applications may require closer vent spacing than the 15m in the general specification. Any other requirement should be given in scheme specific Appendix 17/6.

(12/14) **Grouting Equipment**

5 (12/14) The mixing equipment should be of a type capable of producing a homogeneous grout by means of high local turbulence while imparting only a slow motion to the body of the grout.

(12/14) **Grouting Procedures**

6 (12/14) Unless otherwise agreed with the Overseeing Organisation, or otherwise specified in contract specific Appendix 17/6, grout injection should not exceed the rate of 10 m of duct per minute. For certain applications, where ducts are outside the normal range of size (i.e. not multi-strand tendons in 80-125 mm ducts) this may be increased to 15 m of duct per minute.

To minimise the risk of blockages of pumping equipment or delivery hoses or of lumps forming in the grout, it is advisable to wash out equipment with water at least every three hours. This is especially recommended before grouting very long tendons and in warm weather.

The volume of the spaces to be filled by the injected grout should be compared with the quantity of grout injected, preferably by the use of a flow meter. The grouting records to be supplied to the Overseeing Organisation include the measurements of the grout volume injected into each tendon and expelled from the vents.

Grouting should be undertaken from one end of the duct only, to avoid the risk of voids. In exceptional situations such as looped vertical ducts this may be undertaken from both ends, but the methods should be assessed in full scale trials.

Grouting plant should be located as close as practical to the point of injection to keep supply lines short.

The Overseeing Organisation should adopt a pragmatic approach to the size of acceptable voids in ducts. The limits given in sub-Clause 1711.1 would normally be acceptable at a crest in the duct where the steel tendons are embedded in grout in the lower part of the duct and the vents are properly filled and sealed, and the surface is waterproofed.

It is recommended that where the system includes end caps at anchorages intended to be left in place, these are left undisturbed and completeness of grouting is tested by sounding and visual examination of vent holes in order to avoid disturbing the seals.

The requirements for testing should be included in contract specific Appendix 17/6. Reference should be made to the methods described in Appendix A of TR 72.

(12/14) **Grouting During Cold or Hot Weather**

7 (12/14) The grout materials may be warmed within the limits recommended for concrete (see NG 1710.6).

In cold weather it is necessary to measure the temperature of the concrete structure (for internal tendons) or the air void around the ducts (for external tendons) to comply with specifications to avoid freezing the grout. Air temperature measurement is straightforward but measuring the temperature of the structure can be more difficult.

Recommended procedures are to seal the ducts, say, 12 hours before grouting and measure the air temperature inside the ducts, or to form a small pocket in the concrete, fill it with water, again, say 12 hours before grouting and measure the temperature of this water.

(12/14) **Void Grouting**

8 (12/14) Void grouting should be performed in accordance with the provisions contained in the Concrete Society Technical Report 72.

As for new grouting, there are considerable benefits in undertaking a full scale trial. Typical voids in the trial can be created and then different colour grout for the void filling operation can be used. Non-destructive and intrusive examination of the void grouted ducts can prove confidence in the methods, materials and operatives before embarking on the operations on the structure itself.

The use of void grouting methods constitutes a Departure from Standard, and the specification of materials and methods may be based on that for new grouting and the recommendations of TR 72 until a void grouting specification is available. Variations to the specification for new grouting should be defined through contract specific Appendix 17/6.

Void grouting should be undertaken by organisations certificated by the CARES product acceptance scheme for Void Grouting of Post-Tensioned Systems in Concrete Structures (PT5), or equivalent scheme. However, in exceptional circumstances, where through the lack of a suitable contract full certification cannot be obtained, a firm may be required to have obtained the letter of pre-certification with the scheme.

NG 1712 (12/14) Reinforcement – Materials

(12/14) **General**

1 (12/14) It should be noted that BS EN 10080 does not define steel grades. Therefore, use of BS EN 10080 in isolation would require the designer to specify properties such as yield strength, tensile strength, elongation at maximum force, fatigue strength, weldability, bond strength etc. BS 4449, BS 4482 and BS 4483 simplify the process for designers by specifying the required properties.

BS 4449 specifies three standard grades (B500A, B500B and B500C). With the exception of Grade B500A for nominal sizes below 8 mm, these grades conform to the requirements of BS EN 1992-1-1. Grades B500B and B500C conform to the requirements of BS EN 1992-2, that does not recommend the use of ductility class A reinforcement; however, the UK National Annex to BS EN 1992-2 permits the use of ductility class A for fabric (mesh) reinforcement provided it is not taken into account in the evaluation of the ultimate resistance.

Therefore, for highway structures, Grade B500A reinforcing steel is not permitted, with the exception of fabric reinforcement, where the use of Grade B500A reinforcing steel of nominal size equal or above 8 mm is permitted when not used for ULS (Ultimate Limit State) checks.

BS 4482 specifies requirements for plain, indented and ribbed steel wire. However, Eurocode 2 applies to ribbed reinforcement only, and the properties and rules for the use of indented bars with precast concrete products may be found in the relevant Product Standards (see sub-Clause 1710.8).

It should be noted that reinforcement used in the production of steel fabrics is specified to BS 4449, as standardised grades of reinforcement are not defined in BS 4483.

(12/14) **Stainless Steel Reinforcement**

2 (12/14) The use of stainless steel instead of carbon steel will enhance durability and reduce maintenance and associated traffic delays in those elements of highway structures most at risk from chloride attack. Correctly specified stainless steel with appropriate resistance to corrosion can minimize the damage caused by chloride attack. Designers will need to examine whether the additional expenditure is warranted by the enhanced durability.

Although the unit cost of stainless steel bars can vary between approximately four and ten times that of carbon steel bars (prices are volatile and can vary considerably for different bar sizes and suppliers), for the majority of structures on trunk roads the cost of selective use of stainless steel reinforcement will represent a small percentage of the overall cost of the bridge and can be generally justified in locations like parapet edge beams, on substructures in splash zones adjacent to carriageways, below movement joints on associated bearing shelves, on substructures in marine environments and superstructures subject to spray.

Full substitution with stainless steel reinforcement, which must be subject to a whole life cost benefit analysis and agreed with the Overseeing Organisation, may be appropriate for major components of new structures where future repair and maintenance works would be very disruptive to traffic and very costly. Components that may meet these requirements include decks of bridges carrying heavily trafficked roads over busy railway lines, exposed piers and columns in centre reserves (but not deeply buried elements) and deck slabs where access for maintenance is going to be very difficult because of traffic levels.

Stainless steel reinforcement is generally not appropriate in structures and components that are remote from the carriageway, are unlikely to be exposed to high concentration of chlorides or will not need traffic management for maintenance, and this category is likely to include foundations, piles, buried structures, elements protected by waterproofing and superstructure elements of accommodation bridges and footbridges over the carriageway.

The use of stainless steel may also be justified for the repair and replacement of corrosion-damaged elements that may have suffered widespread chloride-induced corrosion and for modification or strengthening works. In these cases, the stainless steel reinforcement should not be lapped onto bars where corrosion has already started or where chloride levels or half cell readings would indicate corrosion may be imminent, as there are concerns that corrosion resistance may be impaired in this situation and the existing carbon steel may already be active and be vulnerable to bi-metallic corrosion with the stainless steel (this does not apply to new construction where both carbon and stainless steel are cast in new concrete). Very localised repairs, however, may not justify the use of stainless steel as adjacent carbon steel would still be vulnerable.

Since there is a multiplicity of chemical grades of stainless steel, the required chemical grade of stainless steel reinforcement shall be clearly designated and correctly specified. Guidance on stainless steel grade selection is given in Annex B of BS 6744.

(12/14) **Relaxation to Durability Requirements**

(12/14) With the exception of reinforcement bridging joints or penetrating the concrete surface (e.g. dowel bars or holding down bolts), on elements containing stainless steel reinforcement the minimum concrete cover required for durability (see sub-Clause NG 1704.4) can be assumed not more than 30 mm irrespective of the concrete composition and exposure class. However, when relaxation to durability requirements is proposed, the grade of stainless steel appropriate for the relevant service condition should be selected in accordance with Table B.1 of Annex B of BS 6744.

NG 1713 (12/14) Carbon Steel Reinforcement and Stainless Steel Reinforcement – Bar Schedule Dimensions – Cutting and Bending

1 (12/14) Bending of reinforcement should not be carried out when the temperature of the steel is below 5°C. If necessary, reinforcement may be warmed to a temperature not exceeding 100°C. Rules for the allowable diameter of the mandrel are given in BS EN 1992-1-1 as modified by the UK National Annex. Additional information is contained in Annex D of BS EN 13670.

Where it is necessary to bend reinforcement projecting from concrete, the radius of the bend should be not less than that specified in BS 8666, and there should be a clear distance of 4d between the concrete face and the start of the bend. Embedded couplers should be used wherever practicable to avoid damage to concrete and reinforcement.

2 (12/14) Where the Contractor or precast manufacturer opts to cut and bend reinforcement on the site, or in the precasting works respectively, even though the CARES fabricators offer this service, it should be ensured that any fabricated reinforcement not covered by a third party certificated product acceptance scheme such as CARES is assessed by acceptance tests carried out by an independent testing laboratory as specified in BS 8666.

3 (12/14) Re-bending of reinforcing steel can significantly affect its ductility and is therefore not permitted. When the use of continuity strips (i.e. special pre-bent reinforcement housed in a purpose-design carrier casing cast in the front face of a wall which is re-bent ready for splicing the reinforcing of the consequent pour) is proposed, it should be considered as an aspect not covered by Standards and its specification will require submission and approval through the Overseeing Organisation's Departures from Standard processes.

NG 1714 (12/14) Reinforcement – Fixing

1 (12/14) Cover blocks and spacers should be of such materials and designs that they will be durable, will not lead to corrosion of the reinforcement, and will not cause spalling of the concrete cover. The compressive strength, durability and appearance of the cover block should be comparable to those of the surrounding concrete.

BS 7973 (part 1 and 2) provides standardised methods of achieving the specified nominal cover and gives standard performance requirements and methods of testing spacers and chairs. See also sub-Clause NG 1704.4 for concrete cover requirements.

Non-structural connections for the positioning of reinforcement should be made with tying devices or by welding (see NG 1717). Care should be taken to ensure that projecting ends of ties or clips do not encroach into the concrete cover.

The cover and position of reinforcement should be checked before and during concreting; particular attention being paid to the position of top reinforcement in cantilever sections. The support of reinforcement to achieve the correct location, cover and spacing is the Contractor's responsibility and supports should not be shown on the drawings and bar schedules.

Where cover blocks are used in reinforced concrete elements with special surface finishes, the cover block area bearing against the formwork should be minimized.

The concrete cover to reinforcement should be confirmed as soon as possible after the removal of formwork, by the use of non-destructive methods of testing (see sub-Clause NG 1727.2). A record of this survey should be retained for inclusion in the as-built drawings.

The reinforcement drawings must accurately translate the design information for reinforcement into execution requirements and clearly show the location of all reinforcement.

NG 1715 (12/14) Reinforcement – Surface Condition

1 (12/14) Normal handling prior to embedment in the concrete is usually sufficient for the removal of loose rust and scale from reinforcement; otherwise wire-brushing or sand-blasting should be used.

NG 1716 (12/14) Reinforcement – Laps and Joints

(12/14) General Requirements

1 (12/14) Where continuity of reinforcement is required through the connection, the jointing method used should be such that the assumptions made in analysing the structure and critical sections are realised. The following methods may be used to achieve continuity of reinforcement:

(i) lapping bars;

(ii) mechanical joints;

(iii) threaded reinforcing bars;

(iv) welding (see NG 1717).

Such connections should occur, where possible, away from points of high stress and should be staggered. The use of any other jointing method not listed should be confirmed by test evidence.

(12/14) Lapping of Bars

2 (12/14) When lapping reinforcing steel bars, the requirements of Section 8 of BS EN 1992-1-1 apply. When reinforcement is grouted into a pocket or recess, an adequate shear key should be provided on the inside of the pocket.

(12/14) **Jointing of Bars**

3 (12/14) A number of systems are available for jointing reinforcing bars, which are capable of transmitting the tensile and compressive forces in the bar; these are as follows:

(i) swaged couplers;

(ii) tapered threaded bars and couplers;

(iii) upset bar ends with parallel threads and couplers;

(iv) couplers fixed to the bars with studs for transmitting compressive forces only;

(v) sleeves with tapered closers that align the square sawn ends of bars for transmitting compressive forces only.

Mechanical joints for stainless steel reinforcement should have equivalent durability to the reinforcement itself. They require specific approval from the Overseeing Organisation in respect of the technical design requirements.

NG 1717 (12/14) Reinforcement – Welding

(12/14) **General**

1 (12/14) Welding should be avoided whenever possible. Significant loss in fatigue strength of reinforcement can occur as a result of welding. Location welds (tack welds used for locating bars) pose a particular fatigue risk and any welding to shear stirrups requires careful assessment.

Welding may only be undertaken where suitable safeguards, supervision and techniques are to be employed.

Where, notwithstanding the above, welding is to be used, and the fatigue effects of the welds have been taken into account in the design, it should if possible be carried out under controlled conditions in a factory or workshop and should be performed by fabricators holding relevant valid CARES (or equivalent scheme) certificate of approval.

In such circumstances welding may be considered for: fixing in position, e.g. by welding between crossing or lapping reinforcement or between bars and other steel member, and for structural welds, involving transfer of load between reinforcement or between bars and other steel members.

Requirements for welding of reinforcing steels for load-bearing and non load-bearing joints are given in BS EN ISO 17660 (part 1 and 2) and the relevant UK National Annexes, which contain additional guidance and reference to relevant Standards applicable in UK.

NG 1718 (12/14) Prestressing Tendons – Materials

1 (12/14) The characteristic strengths of prestressing tendons are given in the appropriate British Standards. It should be noted that prEN 10138, the European Standard covering prestressing wires, bars and strands, is still to be issued and implemented.

2 (12/14) It should be noted that testing of prestressing steels is now to be performed in accordance with BS EN ISO 15630-3. The fatigue stress range for prestressing steel should be in accordance with BS 5896.

NG 1719 (12/14) Prestressing Tendons – Handling and Storage

1 (12/14) Protective wrappings for tendons should 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 prolonged period, it should 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.

NG 1720 (12/14) Prestressing Tendons – Surface Condition

1 (12/14) All prestressing tendons and internal and external surfaces of sheaths or ducts should be free from loose mill scale, loose rust, oil, paint, grease, soap or other lubricants, or other harmful matter at the time of incorporation in the structural member. Slight surface rusting is not necessarily harmful and may improve the bond. It may, however, increase the loss due to friction and it might harbour harmful chlorides, especially in marine or industrial sites where the use of tendons with surface rusting should be avoided.

Cleaning of tendons may be carried out by wire brushing or by passing them through a pressure box containing carborundum powder. Solvent solutions should not be used for cleaning.

NG 1722 (12/14) Prestressing Tendons – Cutting

1 (12/14) In post-tensioning systems the heating effect on the tendon due to cutting should be kept to a minimum both to avoid damage to the anchorage or bond of the tendon, and to avoid any undesirable metallurgical effects in the tendon steel within the concrete member.

Where tendons between beams on long line prestressing beds are to be cut, the yielding of steel in burning imparts less of a shock load to the beam ends than any cold cutting method. However, on long line prestressing beds the units are first released from the moulds side and pallet and then detensioned gradually, allowing the short lengths of tendon between the beams to be disk cut; flame cutting in this situation can be dangerous in case a debonded strand still has a slight remaining tension and flicks hot metal on to the operator.

NG 1723 (12/14) Prestressing Tendons – Positioning of Tendons, Sheaths and Duct Formers

1 (12/14) The method of supporting and fixing the tendons (or the sheaths or duct formers) in position should be such that they will not be displaced by heavy or prolonged vibration, by pressure of the wet concrete, by workmen or by construction traffic. The means of locating prestressing tendons should not unnecessarily increase the friction when they are being tensioned.

Sheaths and extractable cores should retain their correct cross section and profile and should be handled carefully to avoid damage. Extractable cores may be coated with release agent and should not be extracted until the concrete has hardened sufficiently to prevent it being damaged.

Damage can occur during the concreting operation, and if the tendon is to be inserted later, the duct should be dollied during the concreting process to ensure a clear passage for the tendon. Inflatable rubber duct formers are not suitable for this purpose.

Should the profile of any empty duct be in doubt after the concrete has been cast a technique has been developed of drawing a radioactive source through the duct and plotting its path.

NG 1724 (12/14) Prestressing Tendons – Tensioning

(12/14) **General**

1 (12/14) Tendons may be stressed either by pretensioning or by post tensioning according to the particular needs of the form of construction. In each system different procedures and types of equipment are used, and these govern the method of tensioning, the form of anchorage and, in post tensioning, the protection of the tendons. It should be noted that Clause 7.5.1 of BS EN 13670 requires that information about conformity or non-conformity of the tensioning programme to the requirements, for both pre-tensioned and post-tensioned tendons is recorded in an inspection report.

(12/14) **Safety Precautions**

2 (12/14) A tensioned tendon contains a considerable amount of stored energy which, in the event of any failure of tendon, anchorage or jack, may be released violently. All possible precautions should be taken during and after tensioning to safeguard persons from injury, and equipment from damage, that may be caused by the sudden release of this energy. Further guidance is given in Annex E of BS EN 13670.

(12/14) **Pretensioning**

3 (12/14) The transfer of stress should take place slowly to avoid shock that would adversely affect the transmission length.

(12/14) **Post tensioning**

4 (i) (12/14) Arrangement of tendons. Tendons, whether in anchorage systems or elsewhere should be so arranged that they do not pass around sharp bends or corners likely to provoke rupture when the tendons are under stress.

(ii) (12/14) Anchorage system. The anchorage system in general comprises the anchorage itself and the arrangement of tendons and reinforcement designed to act with the anchorage. The form of anchorage system should facilitate the even distribution of stress in the concrete at the end of the member, and should be capable of maintaining the prestressing force under sustained and fluctuating load and under the effect of shock. No anchorages should be placed in pockets formed in the top surface of bridges decks; however anchorages may be formed in blisters on the soffit of bridge deck slabs. In all cases the detailing recommended for a particular anchorage location should be followed. Guidance is provided in the Concrete Society TR 72.

Provision should be made for the protection of the anchorage against corrosion.

(iii) (12/14) Tensioning procedure. The measured tendon force should be compared with that calculated from the extension, using the Elastic Modulus (E) value for the tendon obtained by measuring the load-extension relationship in a calibrated testing machine with an extensometer of 1 m gauge length. This provides a check on the accuracy of the assumption made for the frictional losses at the design stage; if the difference is significant, corrective action should be taken.

Where a large number of tendons or tendon elements are being tensioned and the full force cannot be achieved in an element because of breakage, slip or blockage of a duct, and if the replacement of that element is not practicable, the designer should consider whether a modification in the stress levels can still comply with the design requirements.

The designer should specify the order of loading and the magnitude of the load for each tendon.

NG 1725 (12/14) Prestressing Tendons – Protection and Bond

(12/14) **General**

1 (12/14) It is essential to protect prestressing tendons from both mechanical damage and corrosion. Protection may also be required against fire damage. Further guidance on protective measures is given in Concrete Society TR 72 and Annex E of BS EN 13670.

(12/14) **Protection and Bond of Internal Tendons**

2 (12/14) Internal tendons may be protected and bonded to the member by cement grout in accordance with Clause 1711. Unbonded internal tendons may be protected by other materials such as bitumen or petroleum based compounds, epoxy resins, plastics and the like.

(12/14) **Protection and Bond of External Tendons**

3 (12/14) A tendon is considered external when, after stressing and incorporation in the work but before protection, it is outside the concrete section. It does not apply, for example, to a slab comprising a series of precast beams themselves stressed with external tendons and subsequently concreted or grouted in so that the prestressing tendons are finally contained in that filling with adequate cover.

Protection of external prestressing tendons against mechanical damage and corrosion from the atmosphere or other aspects of the environment, should generally be provided by a multi-layer system using high density polyethylene or polypropylene and grease or wax.

In determining the type and quality of the material to be used for the protection, full consideration should be given to the differential movement between the structure and the applied protection that arises from changes of load and stress, creep, relaxation, drying shrinkage, humidity and temperature.

If it is required that external prestressing tendons be bonded to the structure, this should be achieved by suitable reinforcement of the concrete encasement to the structure.

NG 1727 (12/14) Inspection and Testing of Structures and Components

(12/14) **General**

1 (12/14) This Clause indicates methods for inspecting and, where necessary, testing whole structures, finished parts of a structure, or structural components to ensure that they have the required standards of finish, dimensional accuracy, serviceability and strength. Where inspection or results of other tests (see NG 1727.2) lead to doubt regarding the adequacy of the structure, loading tests may be made following the procedure set out in NG 1727.6.

In this Clause, deflection means the maximum amount of movement under load of the component being tested, relative to a straight line connecting its points of support. The load tests described in this Clause may not be suitable for:

(i) model testing when used as a basis of design;

(ii) development testing of prototype structures;

(iii) testing to prove the adequacy of a structure, owing to change of use or loading.

Where the Contractor or manufacturer uses a quality control method, and maintains records of the entire process of manufacture (subject to these records being certified by a chartered engineer or a person who has a recognised equivalent qualification of another state of the European Economic Area) which show that the products meet the requirements of the Specification, such records may be accepted as confirming that the required quality has been reached. This in no way precludes the designer specifying such tests as he requires.

Testing requirements should be fully described in contract specific Appendix 17/4 and scheduled in contract specific Appendices 1/5 and/or 1/6.

(12/14) **Check Tests on Structural Concrete**

2 (i) (12/14) General. The testing of concrete specimens to establish whether the concrete used in the structure complies with the Specification as a structural material is described in Clauses 1707 and NG 1707. The tests described in sub-Clause (ii) below are applicable to hardened concrete in the finished parts of a structure or in precast units. They may be used in routine inspection and for quality control. They are also of use when concrete is found defective from visual inspection and when low cube strengths are obtained when assessing the strength of the concrete used. Advice is provided in the Concrete Bridge Development Group Technical Guide No.2 “Testing and Monitoring the Durability of Concrete Structures” (TG2).

If the results of these check tests show that the quality of the concrete is inadequate or shows other defects, the Contractor may propose that a loading test be made. This should then be carried out in accordance with NG 1727.6.

(ii) (12/14) Types of check tests

(a) Cutting cores. In suitable circumstances the compressive strength of the concrete in the structure may be assessed by drilling and testing cores from the concrete. The procedure used should comply with BS EN 13791 and BS 6089. Such cores may also be cut to investigate the presence of voids in the compacted concrete. Core cutting should, whenever possible, avoid reinforcement.

(b) Gamma radiography. Gamma radiography has been used to test concrete up to 450 mm thick for the presence of local voids in the concrete and the efficiency of the grouting of ducts in prestressed members; the presence and location of embedded metal may also be determined. The testing should be carried out in accordance with the recommendations in BS 1881 : Part 205. Special precautions are necessary to avoid contamination from the radioactive source.

(c) Ultrasonic test. If an ultrasonic apparatus is regularly used by trained personnel and if continuously maintained individual charts are kept that show, for a large number of readings, the relation between the readings and the strength of cubes made from the same batch of concrete, such charts may be used to obtain approximate indications of the strength of the concrete in the structure. The procedure should comply with BS EN 13791 and BS 6089. In cases of suspected lack of compaction or low cube strengths, ultrasonic tests carried out on adjacent suspect and acceptable sections of the structure may provide useful comparative data.

(d) Electromagnetic cover measuring devices. The position of reinforcement or tendons may be verified to depths of about 70 mm by an electromagnetic cover measuring device as described in BS 1881 : Part 204. The position of reinforcement and ducts/tendons may be verified to depths of up to 500 mm using an inductive probe as described in TG2.

(e) Rebound hammer test. If a rebound hammer is regularly used by trained personnel and if continuously maintained individual charts are kept that show, for a large number of readings, the relation between the readings and the strength of cubes made from the same batch of concrete, such charts may be used in conjunction with hammer readings to obtain an approximate indication of the strength of the concrete in a structure or element. The procedure should comply with BS EN 13791 and BS 6089. An accuracy of ± 3 N/mm² could be expected when used by trained personnel in these circumstances. Readings should not be taken within 25 mm of the edge of concrete members. It may be necessary to distinguish between readings taken on a trowelled face and those taken on a moulded face. When making the test on precast units, special care should be taken to bed them firmly against the impact of the hammer.

Further advice and extensive guidance on check tests is given in BA 86 ‘Advice notes on the non-destructive testing of highway structures’ (DMRB 3.1.7).

(12/14) **Surface Finish**

3 (12/14) The surface of the concrete should be inspected for defects, for conformity with the Specification and, where appropriate, for comparison with approved sample finishes.

Subject to the strength and durability of the concrete being unimpaired, the making good of surface defects may be permitted, but the standard of acceptance should be appropriate to the strength class and quality of the finish specified and should ensure satisfactory performance and durability. On permanently exposed surfaces great care is essential in selecting the mix proportions to ensure that the final colour of the faced area blends with the parent concrete in the finished structure.

(12/14) **Dimensional Accuracy**

4 (12/14) The methods of measurement of dimensional accuracy, making allowance for specified tolerances, if any, should be agreed in advance of manufacture.

The effect of temperature, shrinkage and imposed load should be taken into account.

The positions of bars, tendons or ducts should be checked where these are visible or ascertainable by simple means (reference sub-Clause 2(ii)(d) of this Clause).

In the case of precast units, the checking of twist, bow, squareness and flatness may entail removal of the unit from its stacked position to a special measuring frame. Extensive checking of units in this manner may materially affect the cost. The frequency and scope of measurement checks should therefore be strictly related to the production method, the standard of quality control at the place of casting, and the function that the unit has to fulfil.

When checking the camber or upward deflection due to prestress, the precast unit should be placed on proper bearings at full span and a central reference point should be provided level with the bearings. The amount of upward deflection to be expected at any stage should be assessed in accordance with BS EN 1992-2. Alternative methods of checking include the use of dial gauges or measurements from a thin wire stretched across the bearings and tensioned sufficiently to take out the sag. Upward deflection is preferably measured on the underside.

(12/14) **Load Tests on Individual Precast Units**

5 (i) (12/14) General. The load tests described in this Clause are intended as checks on the quality of the units and should not be used as a substitute for normal design procedures. Where members require special testing, such special testing procedures should be described in contract specific Appendix 17/4 and scheduled in contract specific Appendix 1/5.

Test loads should be applied and removed incrementally.

(ii) (12/14) Non-destructive test. The unit should be supported at its designed points of support and loaded for 5 minutes with a load equivalent to the sum of the nominal self-weight plus 1.25 times the nominal imposed load. The deflection should then be recorded. The maximum deflection measured after application of the load should be in accordance with requirements defined by the designer. The recovery should be measured 5 minutes after the removal of the applied load and the load then reimposed. The percentage recovery after the second loading should be not less than that after the first loading nor less than 90% of the deflection recorded during the second loading. At no time during the test should the unit show any sign of weakness or faulty construction in the light of a reasonable interpretation of relevant data.

(iii) (12/14) Destructive test. The unit should be loaded while supported at its design points of support and should not fail at its ultimate design load within 15 minutes of the time when the test load becomes operative. A deflection exceeding one-fortieth of the span is regarded as failure of the unit.

(iv) (12/14) Special test. For very large units or units not readily amenable to tests (such as columns, the precast parts of composite beams, and members designed for continuity or fixity) the testing arrangements should be agreed before such units are cast.

(v) (12/14) Load testing of pretensioned beams. Load testing is not normally required and should only be embarked upon when the adequacy of the beams is in serious doubt.

(12/14) **Load Tests of Structures or Parts of Structures**

6 (i) (12/14) General. The tests described in this Clause are intended as a check on structures other than those covered by NG 1727.5 where there is doubt regarding serviceability or strength. Test loads should be applied and removed incrementally.

(ii) (12/14) Age at test. The test should be carried out as soon as possible after the expiry of 28 days from the time of placing the concrete. When the test is for a reason other than the quality of the concrete in the structure being in doubt, the test may be carried out earlier provided that the concrete has already reached its specified characteristic strength. When testing prestressed concrete, allowance should be made for the effect of prestress at the time of testing being above its final value.

(iii) (12/14) Test loads. The test loads to be applied for deflection and local damage are the appropriate design loads, i.e. the nominal self-weight and imposed loads. When the ultimate limit state is being considered, the test load should be equivalent to the sum of the nominal self-weight plus 1.25 times the nominal imposed load and should be maintained for a period of 24 hours. If any of the final self-weight load (in accordance with BS EN 1991-1-1) is not in position on the structure, compensating loads should be added as necessary. During the tests, struts and bracing strong enough to support the whole load should be placed in position, leaving a gap under the members to be tested, and adequate precautions should be taken to safeguard persons in the vicinity of the structure.

(iv) (12/14) Measurements during the tests. Measurements of deflection and crack width should be taken immediately after the application of load and, in the case of the 24-hour sustained load test, at the end of the 24-hour loading period, after removal of the load and after the 24-hour recovery period. Sufficient measurements should be taken to enable side effects to be taken into account. Temperature and weather conditions should be recorded during the test.

(v) (12/14) Assessment of results. In assessing the serviceability of a structure or part of a structure following a loading test, the possible effects of variation in temperature and humidity during the period of the test should be considered.

The following recommendations should be met:

(a) For members spanning between two supports, the deflection measured immediately after application of the test load for deflection should be not more than the specified value. Limits should be agreed before testing cantilevered portions of structures.

(b) If, within 24 hours of the removal of the test load for the ultimate limit state as calculated in NG 1727.6(iii), a reinforced concrete structure does not show a recovery of at least 75% of the maximum deflection shown during the 24 hours under load, the loading should be repeated. The structure should be considered to have failed to pass the test if the recovery after the second loading is not at least 75% of the maximum deflection shown during the second loading.

(c) If, within 24 hours of the removal of the test load for the ultimate limit state as calculated in NG 1727.6(iii), a prestressed concrete structure or member does not show a recovery of at least 85% of the maximum deflection shown during the 24 hours under load, the loading should be repeated. The structure or member should be considered to have failed to pass the test if the recovery after the second loading is not at least 85% of the maximum deflection shown during the second loading.

NG 1728 (12/14) Geometrical Tolerances

1 (12/14) The tolerances given in Clause 1728 are related to the design assumptions of the Eurocodes. They are important for ensuring a safe structure. Tighter or additional tolerances may be required for aesthetics, durability, fit or special structures.

2 (12/14) If the reduced partial safety factors in Annex A of BS EN 1992 are to be used, tighter tolerances should be agreed with the Overseeing Organisation and given in contract specific Appendix 17/4.

(12/14) NG SAMPLE CONTRACT SPECIFIC APPENDIX 17/1: SCHEDULE FOR THE SPECIFICATION OF DESIGNED CONCRETE

(12/14) *[Note to compiler: insert requirements for each designed concrete in the works, expand table as necessary]*

Requirement	**Schedule**		
Designed Concrete Ref / Location in the Works			
Intended Working Life of Structure *[See note to compiler 2]*			
Nominal Cover to Reinforcement *[See note to compiler 2]*			
Applicable Exposure Classes (Excluding DC-class) *[See note to compiler 2]*			
DC-class (where appropriate) *[See note to compiler 1]*			
Compressive Strength Class of Concrete *[See note to compiler 1]*			
Minimum Cement Content (kg/m³) *[See note to compiler 1]*			
Maximum Free Water/Cement Ratio *[See note to compiler 1]*			
Required Group or Type and Class of Cement or Combination (where a DC-class has not been specified) *[See note to compiler 1]*			
Maximum Aggregate Size, mm *[See note to compiler 1]*			
Chloride Content Class *[See note to compiler 1]*			
For Lightweight Concrete, the Density Class or Target Density *[See note to compiler 1]*			
For Heavyweight Concrete, the Target Density *[See note to compiler 1]*			
Consistence Class *[See note to compiler 4]*			
Special Type or Class of Cement or Combination			
Required Source/Special Type of Aggregate			
Maximum Cement Content (kg/m³) *[See NG 1704.7]*			
Required Admixture *[See note to compiler 5]*			
Air Entrainment Required *[YES/NO]*			
Minimum or Maximum Temperature of Fresh Concrete °C			
(12/14) Sampling and Testing *[See 1707 and NG 1707] [See note to compiler 6]*			
(12/14) Requirements to Control Early Thermal Cracking *[See 1704.7 and NG 1704.12]* or Other Requirements *[See Clause 4.3 of BS 8500-1]*			

[Notes to compiler:

1) Denotes basic requirements for designed concrete.

2) Intended working life, nominal cover to reinforcement and applicable exposure classes (other than DC-class) do not form part of the specification to the Contractor or concrete producer but may be listed here because the concrete requirements are dependent on these parameters.

3) In appropriate circumstances any of the above information may be included, but ensure that the requirements specified do not conflict with each other.

4) This shall only be completed for designed concretes where there is a design data requirement for specific consistences.

5) Include here any limiting value / requirement for the essential characteristics of the different types of admixture.

6) Cross-reference should be made to contract specific Appendix 1/5 and/or contract specific Appendix 1/6 as appropriate.]

(12/14) NG SAMPLE CONTRACT SPECIFIC APPENDIX 17/2: NOT USED

(12/14) NG SAMPLE CONTRACT SPECIFIC APPENDIX 17/3: CONCRETE – SURFACE FINISHES

[Note to compiler: Include here:]

1 (12/14) Requirements for trial panels *[1708.1]*

2 (12/14) Requirements for contract specific surface finishes *[1708.4] [cross-referring to the drawings as appropriate]*

3 (12/14) Positions where internal ties are permitted (other than in rebates) for Class F4 finish *[1708.4(i)]*

4 (12/14) Locations where a regular pattern of formwork joints is unnecessary *[1708.4(i)]*

(12/14) NG SAMPLE CONTRACT SPECIFIC APPENDIX 17/4 : CONCRETE – GENERAL

[Note to compiler: This should include:]

1 (12/14) Requirements for concrete if different from the requirements of sub-Clause 1701.1

2 (12/14) Details of any parts of the structure to be constructed in accordance with an execution class other than Execution Class 3 *[1701.4]*

3 (12/14) Additional requirements when using special technologies, other materials or innovative designs *[See NG 1701.4]*

4 (12/14) Whether the use of cements or combinations other than to Clause 1702.1 is permitted

5 (12/14) Requirements for aggregates if different from the requirements of sub-Clause 1702.2

6 (12/14) Requirements for admixtures if different from the requirements of sub Clause 1702.3

7 (12/14) Requirements for sampling and testing if different from the requirements of sub-Clause 1707.1. Whether identity testing is required, the identity test rates and, if not restricted to cases of doubt or random spot checks, type of tests, volume of concrete and number of tests *[Guidance is given in 1707 and NG 1707]. [Cross-reference should be made and tests should be scheduled in contract specific Appendix 1/5 and/or contract specific Appendix 1/6 as appropriate]*

8 (12/14) Requirements for construction joints *[1710.1]*

9 (12/14) Whether retarding agents may be used *[1710.1]*

10 (12/14) Requirements for permanent formwork or special formwork *[1710.2(iv)]*

11 (12/14) Details of parts of the structure for which a curing class other than 3 is to be used *[1710.5(i)]*

12 (12/14) Details of any special curing requirements. *[1710.5(i)]*

13 (12/14) Locations requiring stainless steel wire other than those described in sub-Clause 1714.1

14 (12/14) Whether welding of reinforcement other than steel fabric reinforcement is permitted including details and location *[1717.1]*

15 (12/14) Requirements for time of stressing if different from the requirements of sub-Clauses 1724.3 and 1724.4

16 (12/14) Requirements for protection of prestressing tendons *[1725.1]*

17 (12/14) Requirements for inspection and testing of structures and components *[1701.5, 1701.6 and 1727.1] [Guidance is given in NG 1701.5, NG 1701.6 and NG 1727. Tests should be scheduled in contract specific Appendix 1/5 and/or contract specific Appendix 1/6]*

18 (12/14) Details of parts of the structure that require an independent/third party inspection by an organisation different from that which executed the works *[1701.6 and NG 1701.6]*. Details of who is to procure such inspection and Overseeing Organisation's requirements for approval

19 (12/14) Details of tighter or additional tolerances, required for aesthetics, durability, fit or special structures *[1728 and NG 1728]*

20 (12/14) Additional requirements for stainless steel reinforcement *[1712.6 and NG 1712.2. If stainless steel reinforcement is required the compiler must as a minimum specify the chemical grade of stainless steel required]*

(12/14) NG SAMPLE CONTRACT SPECIFIC APPENDIX 17/5: BURIED CONCRETE

[Note to compiler:

The following information should be completed for each structure, or group of structures, and applies only for buried concrete or partially buried concrete, i.e. with one or more faces in contact with natural or disturbed ground or imported backfill.]

(12/14)

STRUCTURE NAME OR LOCATION *[a separate appendix should be provided for each structure or location with varying conditions or design constraints – identical conditions and constraints may be grouped together in one appendix]*	
ACEC CLASS FOR SITE *[derived from Table A.2 of BS 8500-1]*	
DESIGN CHEMICAL CLASS *[derived from the ACEC class determined by assessment of ground conditions, together with the hydraulic gradient due to groundwater and adjusted as necessary by reference to the footnotes to Table A.9 of BS 8500-1 and NG 1704.11(i) for increase in concrete quality when used as an Additional Protective Measure]*	
OTHER REQUIREMENTS AND DESIGN CONSTRAINTS *[e.g. Any restrictions on cement or combination group, other concrete restrictions, site constraints, limitations on drainage, Additional Protective Measures required etc]*	

(12/14) NG SAMPLE CONTRACT SPECIFIC APPENDIX 17/6: GROUTING AND DUCT SYSTEMS FOR POST-TENSIONED TENDONS

(12/14) **REQUIRED INTENDED USE:**

[Note to compiler – state here the required intended use of the prestressing system]

(12/14) **PERFORMANCE REQUIREMENTS:**

[Note to compiler: state here any performance requirement for the intended use of the system, to be demonstrated by CE marking and Declaration of Performance for the characteristics covered by the relevant harmonized technical specification/ETA of the product. See sub-Clauses 1711.1 and NG 1711.1]

(12/14) **TENDON REFERENCE:**

[Note to compiler: complete this for each different group or type of tendons]

(12/14) **GROUT DEFINITION:**

Grout type:	*Grout*
Maximum water/cement ratio:	*[0.30-0.40]*

(12/14) **REQUIREMENTS FOR TRIALS/TESTS:**

Full-scale grouting trials required: *[Yes/No]*

Drawing Reference: ....

[Note to compiler: full details including trial element size, concrete grade, cover to reinforcement and tendons, reinforcement and tendons details, location of cuts and requirements for testing and investigation should be defined on drawing]

Time at which trials are to be carried out (days before planned use in the permanent works): *[56 days]*
[Note to compiler: Testing requirements to prove protection against ingress of contaminants are given in Section 8 of the Concrete Society Technical Report 72 ‘ Durable Post-tensioned concrete structures’]

Duct assembly tests required	*[Yes/No]*
Required duct assembly testing pressure:	*[0.01 N/mm²]*
Minimum duct wall thickness as manufactured:	*[2.0 mm] [4.0 mm for external tendons]*
Minimum duct wall thickness after tensioning:	*[1.5 mm]*
Minimum duct to concrete ultimate bond length:	*[50-100 diameters]*
Additional testing requirements	*[-]*

(12/14) **REQUIREMENTS FOR DUCT SYSTEM:**

Distance beyond crests to next vent: *[Horizontally, to the point where the duct is half the diameter lower than at the crest, or 1 m, whichever is the lesser]*

Maximum vent spacing	*[15 m]*
Minimum vent height above highest point	*[500 mm]*
Other requirements	*[-]*

Requirements for Grouting:

Maximum rate of grouting of ducts	*[10 m/min]*
Minimum volume of grout expelled after visual test	*[5 litres]*

[Note: Default values shown in brackets]

(12/14) NG SAMPLE CONTRACT SPECIFIC APPENDIX 17/7: PRECAST CONCRETE ELEMENTS

[Note to compiler: Include here:]

1 (12/14) Details of any precast element not conforming to a Product Standard or BS EN 13369 *[1710.8(i)]*

2 (12/14) For each type of precast product, reference to the relevant Product Standard or BS EN 13369 as appropriate *[1710.8(ii)]*

3 (12/14) For each type of precast product, performance requirements for the essential characteristics of the product (which are to be demonstrated by the Declaration of Performance and CE marking in accordance with the Product Standard) *[1710.8(ii) and NG 1710.8(ii)]*

4 (12/14) For each type of precast product, reference to relevant drawings and other technical data prepared by the designer and, where all of part of the design is undertaken by the manufacturer, reference to all information necessary for design *[Guidance is given in NG 1710.8(ii)]*

5 (12/14) For each type of precast product, list of the minimum technical data to be provided with the CE marking stating the required method of CE marking and labelling as defined in Annex ZA of the relevant Product Standard *[Guidance is given in NG 1710.8(ii)]*

6 (12/14) References to documents and drawings which show the lifting scheme and support points for precast concrete elements, including constraints during handling and storage instructions *[1710.8(iv)(b) and (iv)(c)]*

7 (12/14) Requirements for assembly and erection of precast concrete elements *[1710.8(iv)(e]*

8 (12/14) Requirements for jointing and completion works of precast concrete elements *[1710.8(iv)(g) and NG 1710.8(iv)(g)]*