

PUBLISHED DOCUMENT

Recommendations for the design of structures to BS EN 1992-2:2005

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Foreword

Publishing information

This Published Document is published by BSI and came into effect on 31 July 2008. It was prepared by Subcommittee B/525/10, *Bridges*, under the authority of Subcommittee B/525/2, *Structural use of concrete* and Technical Committee B/525, *Building and civil engineering*. A list of organizations represented on this committee can be obtained on request to its secretary.

Relationship with other publications

This Published Document gives non-contradictory complementary information for use in the UK with the Eurocode for concrete bridges, BS EN 1992-2 and its UK National Annex. Background is provided to some of the National Annex provisions where these differ from recommended values.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

The word “should” is used to express recommendations of this standard. The word “may” is used in the text to express permissibility, e.g. as an alternative to the primary recommendation of the clause. The word “can” is used to express possibility, e.g. a consequence of an action or an event.

Notes and commentaries are provided throughout the text of this standard. Notes give references and additional information that are important but do not form part of the recommendations. Commentaries give background information.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

This Published Document is not to be regarded as a British Standard.

Introduction

When there is a need for guidance on a subject that is not covered by the Eurocode, a country can choose to publish documents that contain non-contradictory complementary information that supports the Eurocode. This Published Document provides such information and has been cited as a reference in the UK National Annex to BS EN 1992-2.

It is recommended that reference also be made to PD 6687:2006¹⁾ which contains non-contradictory complementary information that supports BS EN 1992-1. Parts of PD 6687:2006 are relevant to the design of structures to BS EN 1992-2.

NOTE 1 Many of the clauses in BS EN 1992-1-1 are called up in BS EN 1992-2. Although the information provided in this Published Document relates to designs undertaken to BS EN 1992-2, for clarity, clause references are generally provided to the Eurocode part in which the relevant clause is given.

NOTE 2 References are also included to papers and publications that provide additional background or more detailed information associated with a specific issue. It should be noted that these papers and publications might also include material that is not fully in accordance with Eurocode requirements.

1 Scope

This Published Document contains non-contradictory complementary information for use with BS EN 1992-2 and its UK National Annex for the design of concrete structures. It does not cover assessment.

This Published Document gives:

- a) background to the decisions made in the National Annex to BS EN 1992-2 for some of the Nationally Determined Parameters;
- b) commentary on some specific subclauses from BS EN 1992-2;
- c) commentary on the application to bridge structures of some specific subclauses of BS EN 1992-1-1 that are called up in BS EN 1992-2;
- d) guidance on subjects not covered by BS EN 1992-2, but previously included in British Standards and other standards and codes of practice.

¹⁾ PD 6687:2006 is being revised and is to be renumbered PD 6687-1.

2 General

2.1 Definition of National Authority [BS EN 1992-2:2005, Foreword]

Several clauses in BS EN 1992-2:2005 make reference to the “National Authority”. In UK there is no single such body and, therefore, the NA to BS EN 1992-2:2005 defines the National Authority as “the body with a statutory responsibility for the safety of the structure”. Such bodies will not necessarily have “national” coverage, for example in the case of a local Highway Authority. This definition aims to draw those aspects of the design for which reference has to be made to the “National Authority” within established processes of technical approval.

3 Basis of design

3.1 Actions and environmental influences [BS EN 1992-1-1:2004, 2.3.1]

BS EN 1992-1-1:2004, **2.3.1** allows thermal effects, settlements, and creep and shrinkage to be neglected at ultimate limit state provided they are not significant or because the ductility and rotation capacity of the elements affected are sufficient.

In assessing whether the ductility and rotation capacity of elements are sufficient it should be noted that there will be additional demand on the rotation capacity: a) when moment redistribution is carried out; and, b) to cater for differences between the stiffnesses assumed in an elastic design and the true element stiffnesses as the ultimate limit state is approached.

In the absence of a rigorous analysis, for solid sections of constant width, b , it may be assumed that the rotation capacity required to accommodate the differences between the stiffnesses assumed in an elastic design and the true element stiffnesses will not exceed 50% of the allowable plastic rotation capacity determined in accordance with BS EN 1992-1-1:2004, **5.6.3** (4) for sections where the area of main reinforcement exceeds $0.005bd$.

Generally, it will be reasonable to neglect thermal effects, settlements, and creep and shrinkage at ultimate limit state when moment redistribution is not carried out.

3.2 Partial factors for materials [BS EN 1992-1-1:2004, 2.4.2.4 (3) and Annex A]

BS EN 1992-1-1:2004, Annex A should only be used in conjunction with an execution specification that aligns fully with the special control and testing processes required by BS EN 1992-1-1:2004, Annex A and any additional special requirements of the National Authority.

4 Materials

4.1 Creep and shrinkage [BS EN 1992-1-1:2004, 3.1.4]

In the absence of more specific data, the relative humidity may be taken as 70% for the design of bridge structures in the UK.

4.2 Design compressive and tensile strengths [BS EN 1992-2:2005, 3.1.6 (101)P]

The value of α_{cc} in BS EN 1992-2:2005, Expression (3.15) is recommended to be 0.85 for bridges. This value is appropriate for calculations on bending and axial force in BS EN 1992-2:2005, 6.1. However, there are other cases where a value of 1.0 is reasonable, such as for shear calculations, as the empirical model for shear is deemed to account for α_{cc} . Similarly, the membrane rules in BS EN 1992-2:2005, 6.109 already incorporate a 0.85 factor in the formula for direct compressive strength and, therefore, a value of 1.0 for α_{cc} is clearly justified. The NA to BS EN 1992-2:2005, therefore, identifies the clauses for which the value of α_{cc} should be taken as 0.85. For other clauses the value should be taken as 1.0.

The clauses for which the value of α_{cc} should be taken as 0.85 were determined to achieve consistency with the use of 0.85 for bending and axial force and 1.0 for shear. For example, α_{cc} is taken equal to 1.0 in the compression strut limit in BS EN 1992-1-1:2004, Expression (6.56), as this compression limit corresponds to that used in the variable angle shear truss model given in BS EN 1992-2:2005, 6.2 where α_{cc} is also taken as 1.0. Conversely, in BS EN 1992-1-1:2004, Expression (6.63), α_{cc} is given the value of 0.85 in the partially loaded area rules in order to give parity between these rules and those used for calculations of bending and axial force in BS EN 1992-2:2005, 6.1 when the entire cross-sectional area is loaded.

4.3 Confined concrete [BS EN 1992-1-1:2004, 3.1.9]

The general detailing requirements given in BS EN 1992-2:2005 should not be assumed to provide sufficient confinement for the model for increased concrete strength and strain capacity given in BS EN 1992-1-1:2004, 3.1.9 (2) to be used in the general design of elements for bending, axial force, shear and torsion.

The expressions provided for confined concrete may be used in checking triaxially confined nodes, in accordance with BS EN 1992-1-1:2004, 6.5.4 (6).

4.4 Ductility characteristic [BS EN 1992-2:2005, 3.2.4]

BS EN 1992-2:2005, 3.2.4 (101)P allows the classes of reinforcement that may be used in bridges to be defined. The recommended classes are Class B and Class C. The NA to BS EN 1992-2:2005 relaxes this requirement and allows the use of Class A fabric reinforcement provided it is not taken into account in the evaluation of the ultimate resistance.

The restriction on taking account of Class A fabric reinforcement in the evaluation of the ultimate resistance stems from the fact that the ultimate limit state deformation capacity of structures with Class A reinforcement can be very low compared with structures with Class B or Class C reinforcement [1], particularly for lightly reinforced elements. Therefore, its use as primary reinforcement for bridges is not allowed, including its use as shear reinforcement.

Class A fabric reinforcement may be used in the verification of serviceability criteria given in BS EN 1992-2:2005, Section 7 and the minimum reinforcement requirements given in BS EN 1992-2:2005, Section 9.

5 Durability and cover to reinforcement

5.1 Requirements for durability [BS EN 1992-1-1:2004, 4.3]

Half-joints should not be used in bridges unless there are adequate provisions for inspection and maintenance.

6 Structural analysis

6.1 Second order effects [BS EN 1992-1-1:2004, 5.1.4 (1)P]

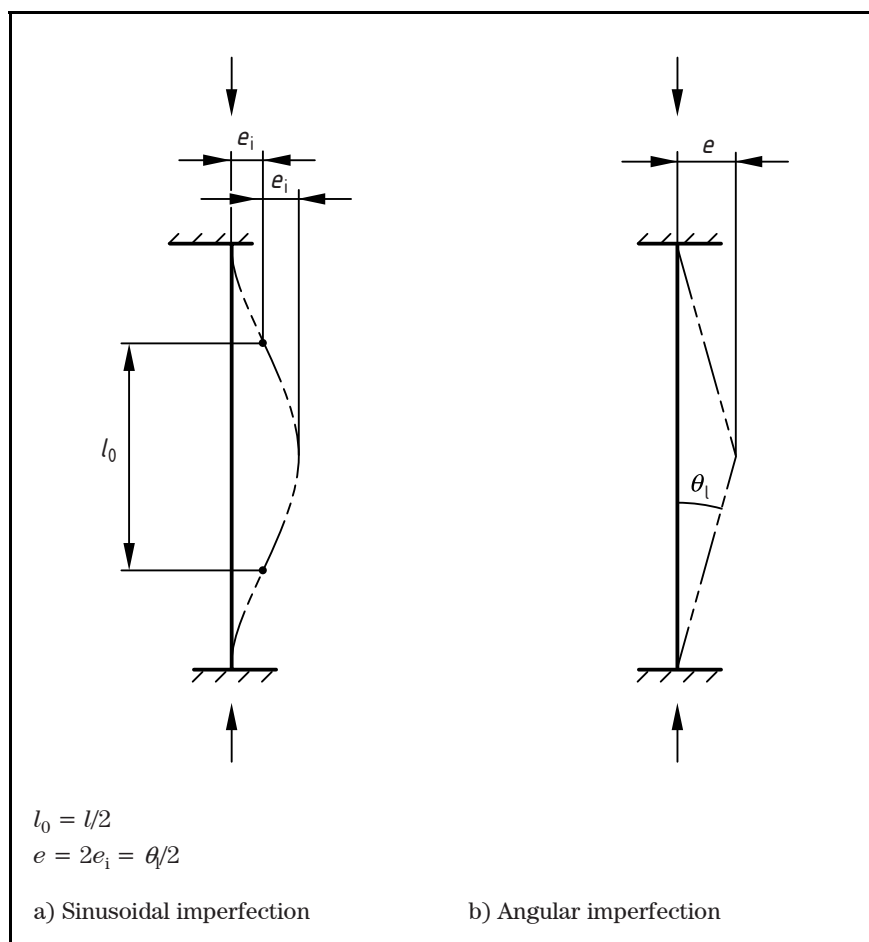
For externally prestressed members, second order effects between deviators, or other points where the tendon position in the section is fixed, need not be considered when the spacing between these points does not exceed 10 times section depth if the tendon force at the ultimate limit state is determined using BS EN 1992-1-1:2004, 5.10.8 (2). If non-linear analysis is used to determine the tendon force, second order effects should be considered.

6.2 Geometrical imperfections [BS EN 1992-1-1:2004, 5.2]

The disposition of imperfections used in analysis should reflect the behaviour and function of the structure and its elements. The shape of imperfection should be based on the anticipated mode of buckling of the member. For example, in the case of bridge piers, an overall lean imperfection should be used where buckling will be in a sway mode ("unbraced" conditions), while a local eccentricity within the member should be used where both ends of the member are held in position ("braced" conditions).

In using BS EN 1992-1-1:2004, Expression (5.2) the eccentricity, e_i , derived should be taken as the amplitude of imperfection over the half wavelength of buckling; Figure 1 shows the imperfection suitable for a pier rigidly built in for moment at each end. A lean imperfection should however be considered in the design of the positional restraints for braced members. Further guidance and background are given in Hendy and Smith [2].

Figure 1 Imperfections for pier built in at both ends



6.3 Linear elastic analysis [BS EN 1992-1-1:2004, 5.4]

The use of fully cracked section properties to derive internal effects in members from indirect actions at the serviceability limit state is not permissible, as the formation of wide cracks implicit in this assumption cannot be accepted at the serviceability limit state. If cracking is considered in global analysis, the member stiffness used should be commensurate with the degree of cracking permitted at the serviceability limit state. This leads to the requirement in BS EN 1992-1-1:2004, 5.4 (3) that a “gradual evolution of cracking should be considered”, which requires a non-linear analysis allowing for the effects of cracking and tension stiffening. Un-cracked global analysis in accordance with BS EN 1992-1-1:2004, 5.4 (2) may always be used as a conservative alternative to such considerations.

6.4 Linear elastic analysis with limited redistribution [BS EN 1992-1-1:2004, 5.5]

If a linear elastic analysis with limited redistribution is undertaken, shears and reactions used in the design should be taken as those either prior to redistribution or after redistribution, whichever is greater.

6.5 Plastic analysis [BS EN 1992-1-1:2004, 5.6]

BS EN 1992-2:2005, 5.6.1 (101)P allows the use of plastic analysis when permitted by National Authorities. Permission for the use of plastic analysis should therefore be sought from the relevant body on a project-specific basis, see 2.1 of this document. Typically this will be part of the technical approval process.

BS EN 1992-1-1:2005, 5.6.2 (5) allows the use of plastic methods to be extended to non-solid slabs if their response is similar to solid slabs. Plastic methods assume that structures have sufficient ductility for a complete collapse mechanism to form before any loss of section resistance occurs. Establishing whether such a condition is generally satisfied is not straightforward [3]. The assessment of whether the response of a non-solid slab is similar to a solid slab should include consideration of whether the non-solid slab will exhibit similar ductility to a solid slab. Particular caution is therefore necessary in cases where torsional hinges might form, because of their limited ductility.

6.6 Rotation capacity [BS EN 1992-1-1:2004, 5.6.3]

BS EN 1992-1-1:2004, 5.6.3 provides a method for verifying rotation capacity. The allowable rotation capacity may be determined from BS EN 1992-1-1:2004, Figure 5.6N, in which the variations in plastic rotation capacity with relative neutral axis depth, x_u/d , are plotted for Class B and Class C reinforcement and for different concrete strengths.

The curves plotted in BS EN 1992-1-1:2004, Figure 5.6N show an initial increase in rotation capacity with increasing neutral axis depth up to a peak value, beyond which the rotation capacity decreases. For neutral axis depths lower than that corresponding to the peak value, the rotation capacity is governed by reinforcement fracture. For higher neutral axis depths it is governed by concrete crushing.

Research has shown that rotation capacity might be subject to a size effect [1], whereby the rotation capacity of geometrically similar elements decreases with increasing size, and might also be lower for non-solid sections compared with rectangular beams and slabs [4]. Neither of these effects is explicitly dealt with in BS EN 1992-1-1:2004, Figure 5.6N.

The issue of size effect was recognized in BS 5400-4:1990, which placed a limit of 1.2 m on the maximum section depth for which moment redistribution was permitted. Therefore, it is recommended that moment redistribution is not used for sections deeper than 1.2 m unless a rigorous analysis of rotation capacity is undertaken.

The reduced rotation capacity of non-solid sections stems from the reduced compressive strain capacity of concrete compression flanges, as discussed in 7.1.1 of this document. This issue is also recognized in BS 5400-4:1990, with the expression for rotation capacity being dependent upon the relative neutral axis depth, x_u/d_e , taking d_e as equal to the effective depth for solid slabs or rectangular beams in a similar manner to BS EN 1992-2:2005, but, for non-solid sections, d_e is taken equal to the depth of the compression flange. This approach may be used conservatively in determining $\theta_{pl,d}$ in accordance with BS EN 1992-1-1:2004, Figure 5.6N. Alternatively, it is recommended that either moment redistribution is avoided or a rigorous analysis of rotation capacity is undertaken.

It will generally be reasonable to assume that the rotation capacity of large or non-solid sections will be sufficient for thermal effects, settlements, and creep and shrinkage to be neglected at the ultimate limit state, provided that no redistribution of moments is undertaken in the analysis. (See also 3.1 of this document.)

A comprehensive review of research on rotation capacity is given in fib Bulletin D'Information No. 242 [1].

6.7 Analysis of second order effects with axial load [BS EN 1992-1-1:2004, 5.8]

6.7.1 Slenderness and effective length of isolated members [BS EN 1992-1-1:2004, 5.8.3.2]

BS EN 1992-1-1:2004, Figure 5.7 of which shows effective lengths of isolated members does not cover typical bridge cases. The more usual bearing types for cantilever bridge piers are not included and cases a) to e) assume infinitely stiff end restraint. For these reasons, additional examples are given in Table 1 of this document.

The values given in Table 1 are based on the following assumptions:

- a) rotational restraint is at least $4(EI)/l$ for cases 1, 2 and 4 to 6, and $8(EI)/l$ for case 7, where (EI) is the flexural rigidity of the column;
- b) lateral and rotational rigidity of elastomeric bearings are negligible;
- c) the height of bearing is negligible compared with that of the column.

Case 4 in Table 1 may also be used with roller bearings provided that the rollers are held in place by an effective means, such as racks.

Where a more accurate evaluation of effective length is required, or where the end restraint stiffness is less than that given in item a) above, the effective length should be derived from first principles (see Jackson [5]).