

PUBLISHED DOCUMENT

Background paper to the UK National Annexes to BS EN 1992-1

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Foreword

Publishing information

This Published Document was published by BSI and came into effect on 31 March 2006. It was prepared by Subcommittee B/525/2, *Structural use of concrete*, under the authority of Technical Committee B/525, *Building and civil engineering*. A list of organizations represented on this committee can be obtained on request to its secretary.

NOTE BS EN 1992-1-1 contains general rules applicable to the design of all concrete structures. Therefore, B/525/10, which is responsible for Eurocodes for the design of bridges, was consulted in the drafting of this Published Document.

Relationship with other publications

This Published Document is a background paper that gives non-contradictory complimentary information for use in the UK with the Eurocode for concrete, BS EN 1992-1 and its UK National Annexes.

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 just such information and has been cited as a reference in the UK National Annexes to BS EN 1992-1.

1 Scope

NOTE During the early stages of implementation of BS EN 1992, all the related European standards and their UK National Annexes might not be available in their final form. Therefore, guidance on the standards that can be used in conjunction with BS EN 1992-1 during the early stages of its implementation is given in Annex A.

This Published Document is a background paper that gives non-contradictory complementary information for use in the UK with BS EN 1992-1-1 and BS EN 1992-1-2 and their UK National Annexes.

This Published Document gives:

- a) background to the decisions made in the National Annexes for some of the Nationally Determined Parameters;
- b) commentary on some specific subclauses from BS EN 1992-1-1 and BS EN 1992-1-2; and
- c) reference to the requirements of the UK Building Regulations 2000 [1] that are not covered in BS EN 1992-1 and its UK National Annexes.

2 BS EN 1992-1-1, Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings

2.1 Partial factors for materials [BS EN 1992-1-1:2004, 2.4.2.4]

The values recommended in BS EN 1992-1-1:2004, **2.4.2.4** have been adopted in the NA to BS EN 1992-1-1.

BS EN 1992-1-1 gives a value of 1,15 for the partial factor for reinforcement γ_s , which is also included in the current British Standard for structural use of concrete, BS 8110-1:1997. This value represents a departure from the value of 1,05 that was used in the now withdrawn BS 8110-1:1985¹⁾. The reason for the change revolves around the characteristic strength, to which the partial factor is applied.

For a normal distribution of yield strengths, the characteristic strength f_{yk} is defined as:

$$f_{yk} = f_{ym} - k\sigma_y$$

where

f_{ym} is the mean value of the strength;

σ_y is the standard deviation of the yield strength; and

k is a factor related to the percentage of test results that are likely to fall below f_{yk} .

¹⁾ BS 8110-1:1985 has been withdrawn and superseded by BS 8110-1:1997.

Traditionally, and in product standards, f_{yk} has been defined as the value below which 5% of the test results are expected to fall. For this percentile the value of k will be 1,64. The statistics from reinforcement production, however, show that the percentage of test results that are likely to fall below a strength of 460 N/mm² [the characteristic value specified in the now withdrawn British Standard for reinforcement BS 4449:1997²⁾] is much less than 5% and the value of k is commonly nearer 2,5 (see Figure 1). Therefore the mean value of grade 460 reinforcement is approximately $(460 + 2,5\sigma_y)$.

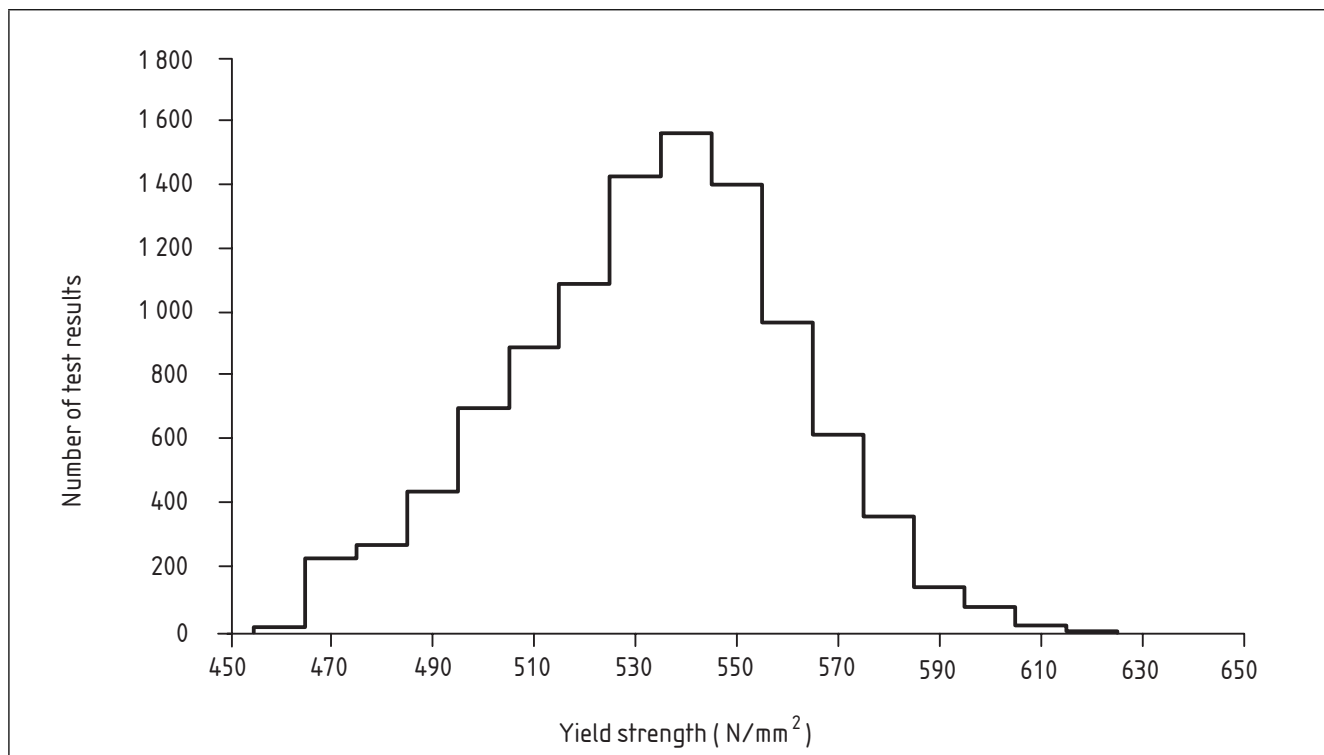
The characteristic value corresponding to the classical 5% value, which is used in the European reinforcement standard BS EN 10080:2005, is much nearer 500 N/mm². The current British Standard for reinforcement, BS 4449:2005, which operates in conjunction with BS EN 10080:2005, now also specifies a characteristic strength of 500 N/mm². Until statistical data for production specified as having this higher characteristic value becomes available, the partial factor of 1,15 should be applied. Therefore there is very little material change to the design values because 500/1,15 is almost the same as 460/1,05.

In summary, there is no change in the material property or in the level of safety. The higher value of the partial factor merely represents the value appropriate to the characteristic value of the yield strength, which conforms to the definition in BS EN 10080.

NOTE One of the reasons for the high level of safety in the design stress for reinforcement was the difference in the relationship between the characteristic strength of reinforcement relative to the actual distribution of yield strengths compared with that specified in reinforcement standards such as BS 4449. This needs to be reanalysed when there is more experience of production to new standards. A brief summary of the procedure adopted for fixing the partial factor γ_s is as follows.

- a) *The value of 1,05 specified in BS 8110-1:1985 arose from an extensive study carried out for the Department of the Environment in the early 1990s. The mean value and the coefficient of variation for resistance were calculated for some 3 000 reinforcement bar sections using data from surveys of variations in section dimensions, variations in material properties and the model uncertainty in prediction equations.*
- b) *The global target reliability index β of 3,8 was split into component parts for load effects $\alpha_E\beta$ and resistances $\alpha_R\beta$ as recommended in BS EN 1990. This gives 3,04 as the appropriate target reliability index for the resistance side of the safety equation $\alpha_R\beta$. It was found that a value of 1,15 for γ_s gave a value in excess of 4 for $\alpha_R\beta$ rather than the generally accepted value of 3,04. It was therefore decided that a reasonable value for γ_s was 1,05, which corresponded to a value of 3,8 for $\alpha_R\beta$, still in excess of the target value of 3,04.*

²⁾ BS 4499:1997 has been withdrawn and superseded by BS 4499:2005.

Figure 1 Distribution of yield strengths of reinforcement ³⁾

2.2 Elastic deformation properties of concrete [BS EN 1992-1-1:2004, 3.1.3]

BS EN 1992-1 recognizes that elastic deformations of concrete largely depend on its composition (particularly aggregates). Therefore the values given in BS EN 1992-1 for creep, shrinkage and elastic modulus should be treated as indicative. These should prove satisfactory for the majority of normal structures. However, it is intended that testing should be undertaken to ascertain the properties of concrete composition used in structures that are likely to be sensitive to deformations and this should be properly specified in the contract documents for a project. The inherent variability of properties should be taken into account using statistical procedures.

2.3 Value of α_{cc} [BS EN 1992-1-1:2004, 3.1.6 (1)P]

Design compressive strength f_{cd} is defined in BS EN 1992-1-1:2004, 3.1.6 (1)P as:

$$f_{cd} = \alpha_{cc} f_{ck} / \gamma_c$$

where

f_{ck} is the characteristic strength of concrete;

γ_c is the partial factor; and

α_{cc} is a coefficient;

which according to BS EN 1992-1-1 takes into account the long-term effects on the compressive strength and unfavourable effects resulting from the way the load is applied.

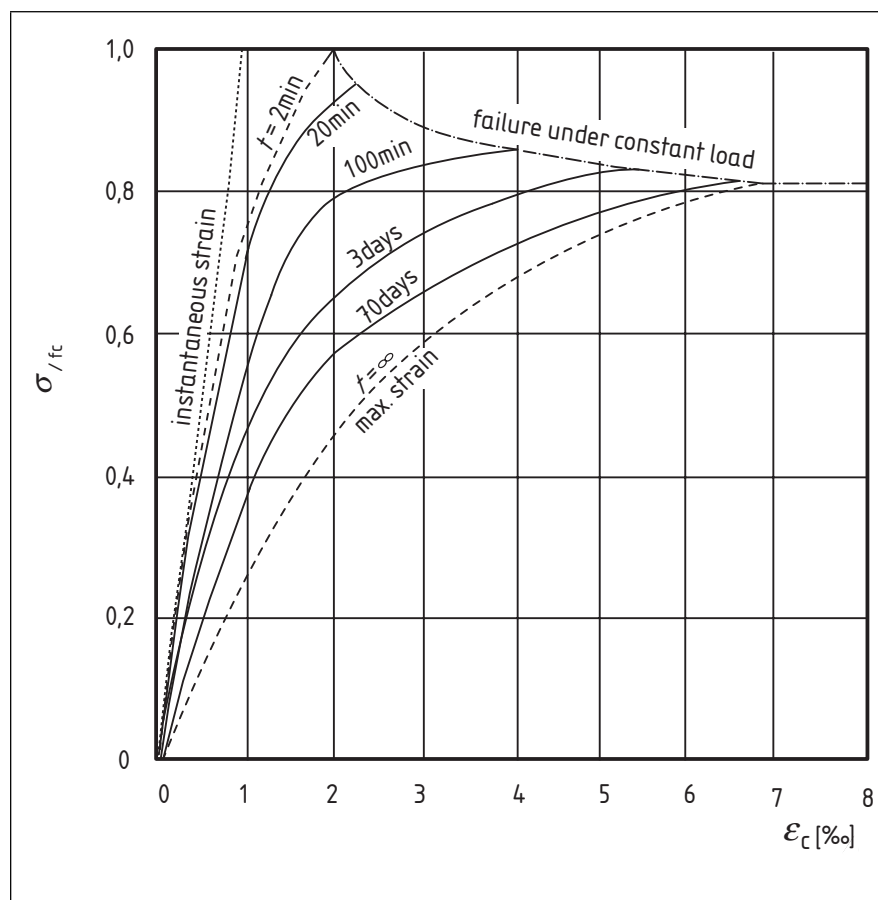
³⁾ Data supplied by reinforcement manufacturers.

BS EN 1992-1-1 recommends a value of 1,00 for α_{cc} but the NA to BS EN 1992-1-1 recommends changing this to 0,85, which was the value used in DD ENV 1992-1-1.

During the development of BS EN 1992-1-1 the following three reasons were given for recommending a value of 1,00 for α_{cc} .

- Based on tests by Rüsch (1960s) [2] it is stated that the stress at failure under constant load depends on the duration of loading. This approaches 80% of the short-term capacity as the duration of loading increases and is higher for shorter duration (see Figure 2).
- The strength at 28 days forms the basis for design calculations. However, in practice when structures receive their design loads they will be older than 28 days and there is an increase in strength of the order of 12% for concrete with normal hardening cement. Therefore a considerable part of the sustained loading effect has already been compensated.
- The resistance equations in design codes such as BS EN 1992-1-1 are derived from laboratory tests with a duration of about 90 min, when the strength of concrete would have already fallen by about 15% compared to the short-term value. Therefore part of the effects for sustained loading has been already built in the resistance equations.

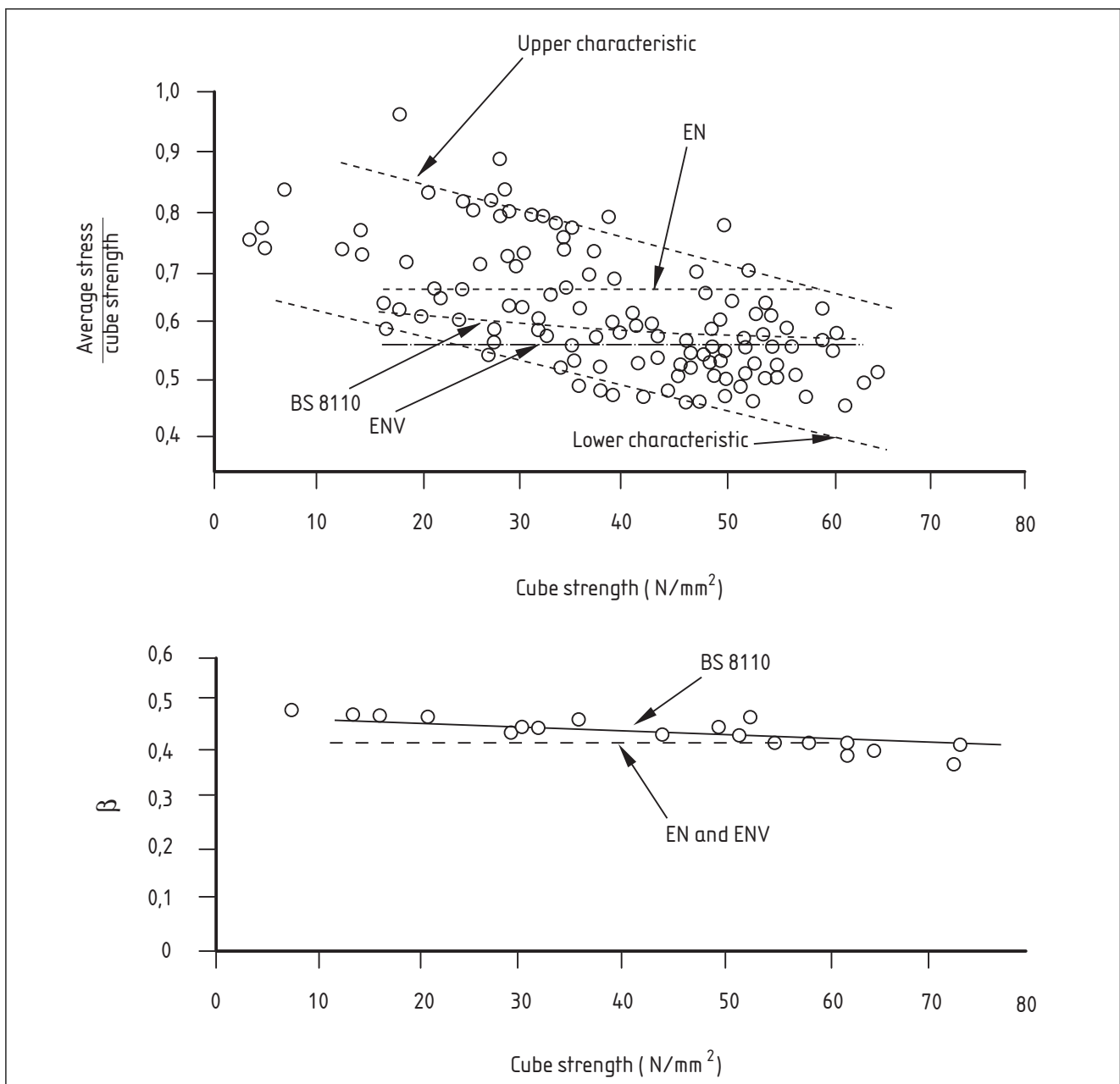
Figure 2 **Stress-strain relationship for axial compression for different durations of loading** ⁴⁾



⁴⁾ Image originally sourced from Rüsch [2].

While the UK does not totally reject the arguments given in a), b) and c), it considers that the comparison of the predicted and experimental compression zone behaviour has been ignored. shows the results obtained by Imperial College and the Prestressed Concrete Association for the average stress in compression zone as a fraction of the cube strength of concrete [3]. At higher levels of strength, DD ENV 1992-1-1 (which recommended 0,85 for α_{cc}) and BS 8110 give something approaching a median prediction and BS EN 1992-1-1 (which recommends 1,0 for α_{cc}) is close to the upper characteristic value.

Figure 3 **Average stress in compression zone and location of the centroid of the compressive force** ⁵⁾

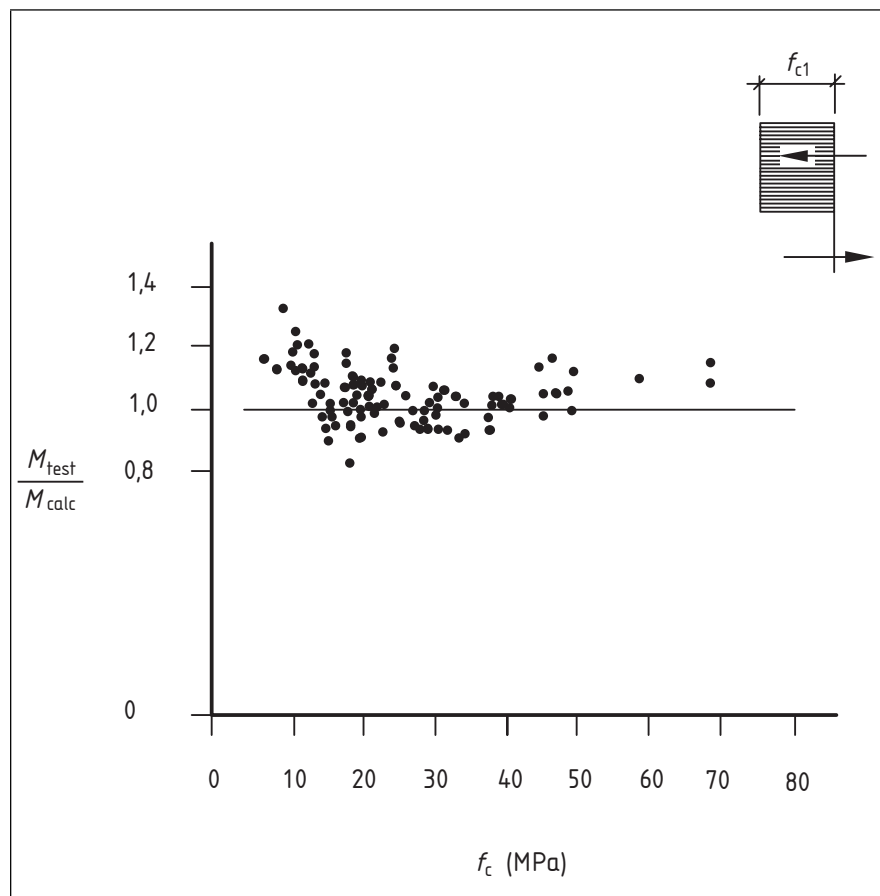


⁵⁾ Image taken from *The design of sections for flexure and axial load according to CP110* by A.W. Beeby [4], obtained from tests carried out at PCA and Imperial College [3].

Figure 4 and Figure 5 reproduce the comparisons of test and calculated values from the International Federation for Structural Concrete (*fib*) bulletin, *Structural Concrete – Text book on behaviour, design and performance* [5]. The figures are calibrations for the proposals in the CEB/FIP Model Code 90 [6]. A value of 0,85 for α_{cc} is built into the model code equations. While these figures show that the model code is conservative for low strengths of concrete, the model code provisions give something close to a “best fit” to the experimental results for higher strengths of concrete. If the factor of 0,85 were removed from the provisions the calculations would predict something close to an upper bound to the data. It seems that α_{cc} is a necessary calibration factor to permit the BS EN 1992-1-1 provisions to predict a reasonable mean value for the stress in compression zone for short-term tests.

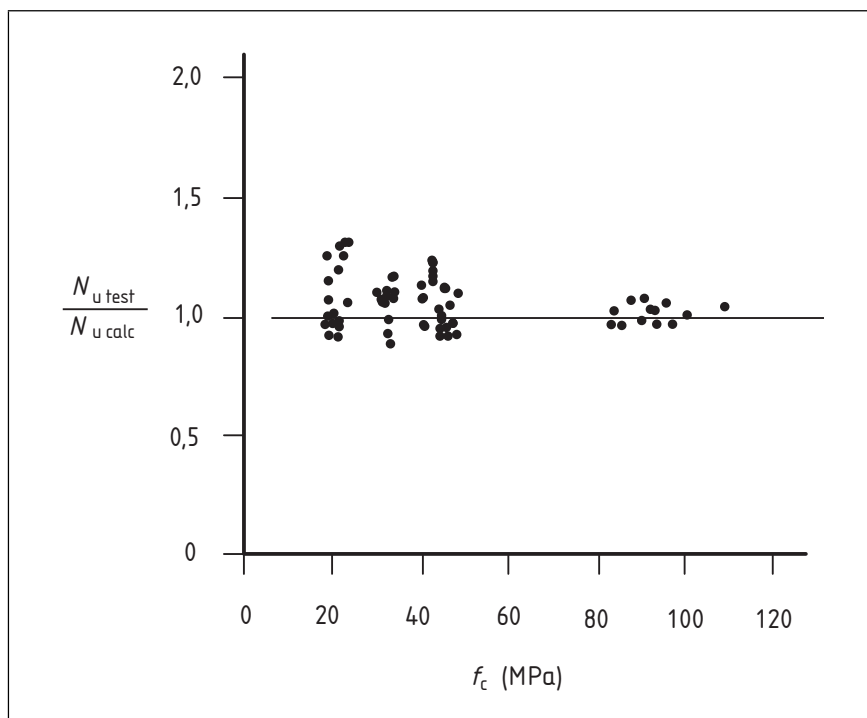
Therefore, a value of 1,0 for α_{cc} is not currently justified in the absence of a proper calibration of BS EN 1992-1-1 provisions against up-to-date test data.

Figure 4 **Comparison of experimental and calculated ultimate moments for over-reinforced beams** ⁶⁾



⁶⁾ Image taken from *Structural Concrete – Textbook on behaviour, design and performance* published by *fib* [5].

Figure 5 Comparison of experimental and calculated strengths of axially loaded columns – Parabolic rectangular diagram for a maximum stress of $0,85f_c$ and a maximum strain of $0,002$ ⁷⁾



Strictly speaking the factor α_{cc} needs to be applied only to concrete compressive strengths related to stress block used for flexure and axial loading including strut and tie models and bearing stresses in the connections for precast elements. Unfortunately, the parameter f_{cd} , as defined including α_{cc} occurs in the resistance models for shear, torsion and web compression (i.e. BS EN 1992-1-1:2004, **6.2**, **6.3** and **6.4**). While there will be no practical consequence if the recommended value of 1,0 had been accepted for α_{cc} , complications in use arise when any other value is chosen. The NA to BS EN 1992-1-1 recommends two values for α_{cc} , namely 0,85 for flexure and axial loading and 1,0 for all other phenomena. However the designer can use the conservative value of 0,85 for all phenomena for pragmatic reasons of minimizing the scope for errors.

2.4 Value of α_{ct} [BS EN 1992-1-1:2004, 3.1.6 (2)P]

Design tensile strength f_{ctd} is defined in BS EN 1992-1-1:2004, **3.1.6 (2)P** as:

$$f_{ctd} = \alpha_{ct} f_{ctk, 0,05} / \gamma_c$$

where

$f_{ctk, 0,05}$ is the characteristic tensile strength of concrete (5% fractile);

γ_c is the partial factor; and

α_{ct} is a coefficient.

⁷⁾ Image taken from *Structural Concrete – Textbook on behaviour, design and performance* published by fib [5].