

Implementation of Eurocode 2 within the UK

Dr Tony Jones, Associate Director, Arup Research & Development summarises the introduction into the UK of Eurocodes for design of concrete buildings and the documentation required to carry it out

This technical note summarises the documents required to carry out the design of a concrete building to the Eurocodes. A brief review of the main codes is given and then the role of the 'non-contradictory complementary information' document PD 6687 is discussed. A review of the main areas covered by the PD demonstrates that it is an essential document for UK designers to be familiar with and that it should ease the transition between BS 8110 and EC 2.

Introduction

The suite of Eurocodes and supporting documents necessary for the design of concrete buildings within the UK have now been published. The principal documents are:

- BS EN 1992-1-1: 2004: *Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings*¹
- UK National Annex to BS EN 1992-1-1: 2004: *Eurocode 2: Design of concrete structures – Part 1-1: General rules and rules for buildings*²
- BS EN 1992-1-2: 2004: *Eurocode 2: Design of concrete structures – Part 1-2: General rules – Structural fire design*³
- UK National Annex to BS EN 1992-1-2: 2004 *Eurocode 2: Design of concrete structures – Part 1-2: General rules – Structural fire design*⁴
- PD 6687:2005: *Background paper to the UK National Annex to BS EN 1992-1-1 and BS EN 1992-1-2*⁵
- BS 8666: 2005: *Specification for scheduling, dimensioning, bending and cutting of steel reinforcement for concrete*⁶
- BS EN 206-1: 2000: *Concrete – Part 1: Specification, performance, production and conformity*⁷
- BS 8500-1 & 2: *Concrete – Complementary British Standards to BS EN 206-1*⁸.

(Note: The essential information in the last two documents are noted in the National Annex to BS EN 1992-1-1 and PD 6687)

Currently design to British Standards, and specifically to BS 8110^{9,10}, is still possible but as the various supporting standards are revised in line with the Eurocodes its relevance will diminish. Under current CEN rules BS 8110 will need to be withdrawn in 2010; however it is possible that, as its relevance reduces, the British Standards Committee responsible may decide to withdraw it earlier.

This note discusses concrete building design within the context of the Eurocode system but specifically concentrates on the importance of Published Document (PD) 6687 on the implementation of the Eurocodes within the UK.

Load factors and loading

Before commencing the design of the concrete elements it is necessary to ascertain the appropriate load factors and loading. Load factors are covered by BS EN 1990¹¹ *Basis of structural design* (EC0) and its National Annex¹². Whilst different factors are given for different situations for concrete elements there will generally be the choice of two approaches. The first approach is the use of a single relationship (Code Expression 6.10), the second involves carrying out the design using two different sets of load factors and taking the more onerous (Code Expressions 6.10a and 6.10b). The factors for a typical concrete design incorporating the UK National Annex requirements are shown in table 1. It should be noted that Eurocodes adopt the comma (,) as the decimal symbol and, for consistency, it is also used throughout this note. It

Table 1: Typical load combinations

Expression from EC0	Permanent Action		Variable Action	
	Unfavourable	Favourable	Leading/Main	Others
Exp 6.10	1,35 G _k	1,0 G _k	1,5 Q _{k1}	1,5 ψ ₀ Q _{kj}
Exp 6.10a	1,35 G _k	1,0 G _k	1,5 ψ _{0,1} Q _{k1}	1,5 ψ ₀ Q _{kj}
Exp 6.10b	1,25 G _k	1,0 G _k	1,5 Q _{k1}	1,5 ψ ₀ Q _{kj}

ψ₀ is a combination factor which varies for different types of variable actions and can be found from EC0

remains to be seen which symbol will be used by British engineers in their calculations.

Whilst the use of Code Expressions 6.10a and 6.10b would appear to require more effort it can be shown that, for all types of loading other than storage, Code Expression 6.10b governs unless the permanent action is more than 4,5 times the variable action. Code Expression 6.10b has a lower load factor on the permanent action and will therefore produce more economic designs than Code Expression 6.10. However it should also be noted that where there are two variable actions the loading is always worse than the consideration of just the leading variable action. This is completely different to BS 8110 where it was often possible to show, for example, that 1,4 times the dead load plus 1,6 times the live load was more significant than 1,2 times the dead load, live load and wind load for an element. It is therefore suggested that where simplified analysis is carried out Code Expression 6.10 should be used, and Expressions 6.10a and 6.10b are only used when the analysis clearly takes into account the interaction of all loads on the element. The PD deals with the application of Exp. 6.10 (a) & (b) to continuous structures.

The value of loads (actions) to design for is covered in the various parts to Eurocode 1 (EC 1)¹³, one significant change is that the bulk density of reinforced concrete is given as 25kN/m³; however most loading is similar. Indeed PD 6687 makes the point that EC 2 and its UK National Annex were calibrated against the then current British Standards for loading and where parts of EC 1 are not available the corresponding British Standard loading code may be used.

Eurocode 2

This paper is not intended to provide technical guidance on the use of EC 2 for which reference should be made to the various design guides, manuals and leaflets^{14,15,16}. However a brief overview of the principle documents and how they differ from BS 8110 is provided here. The documents that make up EC 2 are as follows:

- BS EN 1992-1-1:2004 Eurocode 2: *Design of concrete structures – Part 1-1: General rules and rules for buildings*.
- BS EN 1992-1-2:2004 Eurocode 2: *Design of concrete structures – Part 1-2: General rules – Structural fire design*.
- BS EN 1992-2:2005 Eurocode 2: *Design of concrete structures – Part 2: Reinforced prestressed concrete bridges*¹⁷.
- BS EN 1992-3:XXXX Eurocode 2: *Design of concrete structures – Part 3: Liquid retaining and containing structures* (not yet published)¹⁸.

At the time of writing National Annexes were only available for the first two documents, i.e. those required for the design of buildings.

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The design content of EC 2 exceeds that covered by BS 8110 parts 1 and 2. It is probably reasonable to say that EC 2 contains the most up-to-date set of design requirements of any code around the world. Its drafting drew heavily on the Model Code 90¹⁹ which was itself drafted by leading experts from across the world. This does not however mean it is the easiest code to design to. EC 2 often provides the rules for design but leaves the practical interpretation of these rules to the engineer, as there was a strong desire during the drafting of the code that it should not include 'text book material'. This will surprise many UK users who are used to the simplified methods and design aids included in BS 8110, and this is one area where it is hoped the PD 6687 will help.

The layout of EC 2 relates to the phenomena to be designed for rather than on an element by element basis, so for example shear is treated in one section for all element types, whereas BS 8110 would refer to shear under the design of each type of element. The EC 2 approach avoids the need to repeat text or to refer to previous sections which is advantageous; however it also means that to design one element various parts of the code need to be referred to.

The National Annexes are an integral part of the Eurocode system. They provide the national decisions on the choice of certain key parameters, principally affecting safety (known as Nationally Determined Parameters or NDPs). Those for EC 2 Parts 1-1 and 1-2 have been prepared by the BSI committee responsible for structural concrete. They also note which of the informative Annexes to the main code may be used in that nation. National Annexes may also make reference to 'non-contradictory, complementary information'. That

is material that is considered to complement that already in the code. The UK National Annex refers to several published guides and papers which give specific guidance in areas such as post tensioned slabs, reinforcement detailing and deflection. However it also refers to PD 6687:2005, Background paper to the UK National Annex to BS EN 1992-1-1 and BS EN 1992-1-2. This document is discussed below.

PD 6687

PD 6687 was also prepared by the BSI committee responsible for structural concrete and was published as a BSI document in February 2006. The introduction to the PD notes its purpose as providing:

1. background to the values chosen for some of the NDPs;
2. commentary on some specific code clauses; and
3. requirements, which are additional to those in the code and National Annex, to comply with the UK Building Regulations.

As such the PD should be considered as part of the suite of documents forming EC 2 as implemented within the UK. Principal areas covered are summarised below.

Related codes and Standards

The PD acknowledges that during the implementation of the Eurocodes not all parts of the Eurocode system will be in place. The PD therefore makes recommendations as to what alternative documents can be used to give the required reliability. As discussed above this includes the recommendation to use the existing British Standards for loading where the particular parts of EC 1 are not available. The PD also discusses the problems of specification of workmanship. EC 2 is written assuming that the requirements of ENV 13670²⁰ for execution and workmanship are followed however this document is not available in the UK. The PD therefore confirms that use of the National Structural Concrete Specification²¹ is considered equivalent.

Partial factors for materials

The UK National Annex for EC 2 adopts a material factor of safety for steel of 1,15 as does the latest version of BS 8110. The PD goes to some length explaining the rationale behind this decision and setting out the criteria for any future reduction back to 1,05.

Value of α_{cc}

In EC 2 the design compressive strength of the concrete, f_{cd} , is given as $\alpha_{cc} f_{ck} / \gamma_c$, where f_{ck} is the characteristic concrete cylinder strength, γ_c is the concrete material partial safety factor (1,5) and α_{cc} is a coefficient, which effectively corrects the equation to match the results of tests. The recommended

value of α_{cc} given in EC 2 is 1,0. The value of α_{cc} given in the UK National Annex is 0,85 for compression and flexure (which gives values similar to BS 8110) and 1,0 for other phenomena. The PD provides the background to this decision.

Reinforcement type and EC2

EC 2 only covers ribbed reinforcement, however the PD notes that the general approach of EC 2 may be used for other bar types, such as plain. The PD highlights the specific areas that require further consideration, in particular bond rules for plain bars are given. It should be noted however that mild steel bars are no longer covered by the reinforcement standard BS 8666, and so their use in concrete construction will be limited to very specific applications.

Allowance in design for deviation in cover to reinforcement

In EC 2 an allowance is added to the minimum required cover to allow for deviation during construction. EC 2 specifies this allowance as 10mm but then gives situations where this may be reduced. The PD gives more guidance on the interpretation of the rules for reducing this allowance. In particular when covers are monitored by inspection as part of a recognised quality scheme (e.g. as required to be operated by members of SpeCC – the registration scheme for Specialist Concrete Contractors) the value may be reduced to 5mm. The minimum required cover for the various exposures is given in the UK National Annex in tables derived from BS 8500.

Simplified load combinations

EC 2 allows the National Annex to specify simplified load cases. In the UK the National Annex allows those combinations which have been used successfully in BS 8110 that is:

- all spans loaded and alternate spans loaded, the PD notes that in EC2 it is acceptable to have the same load factor on the permanent load for both the loaded and unloaded span, and discusses the implications of this
- for slabs only, under certain conditions, the single load case of all spans loaded. The PD provides the justification for this decision, which considerably simplifies design of these slabs.

Calculation of effective length of columns

EC 2 defines the effective length of a column in terms of the stiffness of its end joints. Calculating this joint stiffness requires a significant amount of interpretation. For example, how significant is the effect of cracking on the stiffness of attached beams? Are attached and adjacent columns restraining or contributing to the slenderness of the column under consideration? Assessment of this from first principles

is time consuming particularly when compared to the look-up table, based purely on beam depth, in BS 8110. The PD discusses this problem and proposes a simplification for a frame of columns of similar stiffness. This simplification will generally yield similar effective lengths to BS 8110. The PD also discusses the basic philosophy of assuming that the column under consideration has ultimate material properties whilst those in the rest of the structure have average material properties. This should help those carrying out analysis outside the simplified cases covered directly by the PD.

Design moments in columns

The PD provides further advice on the interpretation of column design moments from EC 2. In particular guidance on how to combine the additional moments from slender columns to other moments is given.

Stress limitation in serviceability limit state

EC 2 requires both the compressive stress in the concrete and tensile stress in the reinforcement to be limited. The method of checking and the reasons behind the checks for compressive stresses are rather vague in the code. The PD suggests that for most cases such checking of compressive stresses will not be necessary, the obvious exception to this is in prestressed concrete design. The PD proposes the value of modular ratio (15) to be used for the tensile stress checks.

Crack widths

The PD notes that EC 2 part 1 does not explicitly cover the calculation of crack widths due to restrained imposed deformations. This will be covered in EC 2 Part 3 but in the interim the PD provides guidance. It is also noted that EC 2 only provides calculation models for calculating crack widths for rectangular sections. The PD provides an alternative model broadly based on that in BS 8110: Part 2 to cover other shape sections.

Span/depth ratios

The PD provides some warnings in using the standard span-to-depth ratios given in EC 2 when early striking of formwork is likely. In addition, the limit on increasing the tension reinforcement to control deflection, given in the UK National Annex, is explained.

Tying requirements to comply with UK Building Regulations

Following the tying rules in BS 8110 is currently recognised as a valid method of satisfying the UK Building Regulations. Whilst there are some tying rules in EC 2 they are not sufficient to meet the Building Regulations. The PD provides additional rules such that structures designed to EC 2 and

the requirements of the PD will meet the Building Regulations.

Detailing rules for particular situations

EC 2 Part 1-1 provides additional detailing rules in an informative Annex J. As an informative Annex each nation can decide whether to adopt, or whether to refer to some alternative rules. Annex J of EC 2 Part 1-1 covers surface reinforcement, the use of such reinforcement was not considered normal practice in the UK and in the cases where it may be required it was considered better to calculate from first principles. Annex J also covers detailing of frame corners; it was felt the Annex did not adequately allow for the higher strength concretes allowed by EC 2, nor current UK detailing practice. An alternative Annex is included in the PD to cover this area.

Structural fire design – tabular method for columns

EC 2 provides tabular methods for the fire design of elements, yet unlike BS 8110 the tabular methods for columns are somewhat more complicated requiring knowledge of loads and, for one of the methods, reinforcement. They also place restrictions on the moment carried in the column via

consideration of an effective eccentricity. They are not applicable to columns in unbraced structures. The PD suggests that for unbraced structures the same tables may be used and provides some justification for this, however it is recommended that the critical cases are checked using the more advanced methods available in EC 2.

Conclusions

The documentation required to design concrete buildings to the Eurocodes is now available within the UK. This comprises the various parts of EC 2 that relate to buildings and their National Annexes. However another important document in terms of how EC 2 is implemented within the UK is PD 6687. This document provides useful background information to the choices made within the UK National Annex, but more importantly for those designing structures it provides interpretation of some clauses within EC 2 and contains additional rules for compliance with UK Building Regulations. As such PD 6687 should be considered an essential part of the EC 2 family for those designing concrete buildings. The PD will also help those familiar with the concepts in BS 8110 to make the transition to EC 2. se

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