Eurocode 2: Design of concrete structures

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Introduction

The transition to using the Eurocodes is a daunting prospect for engineers, but this needn’t be the case. Industry has worked hard to ensure that there are numerous resources available, designed to assist engineers with the transition process. The key to getting into Eurocode 2 is to understand how it is set out and how it is different from existing standards. This article covers these topics and explains how Eurocode 2 fits in with other European standards. The good news is that most of the engineering principles are the same as the existing British Standards. For existing engineers is should not be like learning to drive, more like getting into a strange car for the first time – the controls are all there but it takes a few miles to learn where they are and how they operate.

A standard or a handbook?

The first difference that British engineers will come across is that Eurocode 2 does not appear to tell you how to carry out design. In Europe standards are very much seen as setting out the rules, the application of those rules is left to authors of text books or design guidance. In many ways British Standards are far more like design handbooks and provide far more practical material than other Europeans would expect to see in their standards. This why British engineers find that it does not provide the information they are expecting. A good example of this is the design expression for flexure. In British Standards we are used to being given the expressions for the lever arm, areas of steel
and limiting values for K. These are not given explicitly in Eurocode 2 and in fact there appears to be very little guidance on flexural design, other than the stress blocks that can be used. However, help is at hand because this information is available in text books, and in the design guides that have been prepared by The Concrete Centre.

**A stand alone document?**

It is important to realise that the Eurocodes are supported by a number of European Standards; these are not themselves designated as Eurocodes, but nonetheless are required to enable the Eurocodes to be used. Figure 2.1 shows how Eurocode 2 fits into the Eurocode system.

The first point to note is that Eurocode 2 has four Parts. The main Part is Part 1.1 and this gives general rules for all structural concrete and specific rules for buildings. Often it is this part that is being referred to when citing ‘Eurocode 2’.

Part 1-2 covers structural fire design and at first it seems a bit imposing to have over 100 pages on fire design when a few tables sufficed in BS 8110. However, the good news is that this Eurocode does have simplified tables in Section 5 and so designers will continue to be able to check that their design meets the requirements for fire resistance with a quick reference to a table. The remainder of the document is devoted to simplified and advanced calculation methods. The former may be useful to the structural engineer for specific situations, for example a column with an eccentric load. However, advanced methods are probably the reserve of fire engineering specialists.

Bridge designers will need to refer to Part 2, which describes how Part 1.1 should be amended to suit bridge designs. This sounds simple in theory, but in practice it is rather complicated to work out which clauses are deleted, which are amended and which are new clauses, especially when the national annexes to both documents are factored in.

The final Part of Eurocode 2 is Part 3, which covers the design of water containing structures. Again, it modifies Part 1.1, but in practice it includes additional clauses to aid the design of liquid containing structures and so it is far simpler to apply.

Designers of concrete structures will need to determine the actions on their structures and these are given in Eurocode 1. They will also need to determine
The essential guide to Eurocodes transition

The combination of these actions, and these are given in Eurocode (often incorrectly called Eurocode 0).

Any structure has to have foundations, and as these are usually concrete the concrete designer will also have to refer to Eurocode 7 to determine the load carrying capacity of the ground.

Occasionally in the UK there is the need to design for seismic conditions and for the first time this is covered by a UK standard – Eurocode 8.
Supporting European Standards

Moving on from the links between Eurocodes to look at other European Standards, UK designers should already be familiar with most of them. Specification of concrete is covered in BS 8500, which is the UK application document for BS EN 206-1. This document was originally published in 2002 and so designers should be familiar with its contents already. It brought a new approach to determining the durability resistance of concrete based on the deterioration processes.

At this point it should be noted that the BS 8500 approach to durability does not follow the approach in Eurocode 2, rather it is cited in the UK national annex to Part 1.1.

A key change in BS 8500 was the introduction of the dual classification system where the concrete cylinder strength is given alongside the equivalent concrete cube strength.

Other standards which UK designers should already have adopted are BS 4449 and BS 8666, which cover the specification and detailing of reinforcement. Here the key change is that the characteristic strength of reinforcement supplied in the UK is 500 MPa; previously the minimum strength was 460 MPa. To ensure that there was no confusion with the older steel grades the 500 grade steel is designated with an ‘H’.

There is a suite of European products standards for precast concrete elements, e.g. hollowcore units and double-tee units. The over-arching standard is BS 13369, which sets out the requirements for all precast concrete products such as tolerances, durability and design.

The final piece of the jigsaw is BS EN 13670 which is the execution standard, execution being the European term used to cover construction. At the time of writing this publication has been finalized and is due for publication in the UK in time for the March 2010 transition date. The document replaces Section 6 of BS 8110 which covered workmanship and has been written to tie-in with Eurocode 2. A UK national annex will be published alongside the standard. Standard specifications, such as the National Structural Concrete Specification (NSCS) and National Building Specification (NBS) will be updated to incorporate the changes.
Non-Contradictory Complementary Information

Non-Contradictory Complementary Information (NCCI) is a specific term in the Eurocodes that refers to documents that may be used alongside a specific Eurocode and which do not contradict that Eurocode. NCCI are listed in the relevant national annex only. The two key NCCI in the UK for concrete design are PD 6687 Background Paper to the UK national annexes to BS EN 1992-1 and PD 6687-2: Recommendations for the design of structures to BS EN 1992-2. ‘PD’ stands for published document and are published by BSI. The two documents have been prepared by the relevant BSI committee and provide background information to the choices made for the UK national annexes. They also give useful guidance and designers will find that they are almost essential to enable them to use Eurocode 2.

How is Eurocode 2 different?

The question that is often asked is, ‘What are the differences between British and European Standards?’ There are differences of course, but engineers should not overlook the similarities and in this chapter we will consider both.

Eurocode 2 is laid out on the basis of the phenomenon (e.g. flexure, shear, deflection) and not by element type (e.g. beam, flat slab). This makes the code more useful and engineers are not straitjacketed by thinking only in terms of the type of element. As we make more use of computer-aided engineering to be more creative in our designs, treating elements strictly as say beams or columns may not be appropriate.

Eurocode 2 uses concrete cylinders strengths, rather than cube strengths as the basis for the design calculations. This is not, as many think, because cylinders are used in continental Europe, but rather that cylinders have been used in the laboratories when testing samples and have therefore been used to develop design rules. It therefore makes more sense to use them as the basis for design. Testing of cubes can still be used to monitor concrete strength as Eurocode 2 gives the equivalent cube strengths.

In Eurocode 2 the units of stress are mega-Pascals (MPa), although interestingly Eurocode 6 still uses Newtons per square millimetre (N/mm²).

In line with European conventions, the decimal marker is denoted by a comma, rather than a full stop. This is not necessarily a problem, provided
that it is recognized by the reader. British Engineers can continue to use the full stop in their workings, but may like to consider avoiding the use of the comma as a thousands separator.

There is a new symbol that UK engineers may not be familiar with – ‘‰’, which means a thousandth.

Designers will also find that there is a new method of presenting equations (known as ‘expressions’ in Eurocodes). For example, minimum cover is:

\[ c_{min} = \max\{c_{min,b}; c_{min,dur}; 10 \text{ mm}\} \]

which means that \( c_{min} \) is the maximum of \( c_{min,b} \) (minimum cover for bond) \( c_{min,dur} \) (minimum cover for durability) and 10 mm.

Designers should note that the effect of geometric imperfections should be taken in addition to any lateral loads. There is no longer the philosophy of checking for either notional horizontal loads or actual lateral loads.

Eurocode 2 allows the designer to use high strength concrete, up to a class C90/105 (or class C70/85 for bridges). Above a class C50/60, the engineer will find that there are restrictions placed in Eurocode 2. For instance, there are lower strain limits, additional requirements for fire resistance and in the UK the resistance to shear should be limited to that of a class C50/60 concrete.

On the subject of shear, Eurocode 2 uses the variable strut inclination method. It is assumed that shear is resisted by a concrete strut and the shear links and longitudinal steel are acting in tension to form a truss. The designer can vary the concrete strut angle in the truss (whereas in BS 8110 and BS 5400 it was fixed at 45°). This has the advantage of including more shear links in the truss and so reduces the reinforcement requirements.

Still looking at shear, punching shear checks are based on \( 2d \) away from the column face and the perimeters have rounded corners.

Prestressed design is not treated as a separate process and the design expressions are written to include the effects of prestressing where appropriate.

For the determination of the anchorage and lap lengths the designer will find that Eurocode 2 is not restrictive and could enable savings to be made by applying all of the benefits. Conversely, the designers will need to work out how to rationalize the calculations for typical situations or refer to design aids where this has already been done.
Perhaps the biggest challenge is the new symbols, but they will become familiar over time. The Eurocodes follow some clear guidelines for use of symbols and so there is consistency, which assists the learning process. Figure 2.2 provides some typical subscripts found in Eurocode 2 and once they are familiar it is much simpler to work out the meaning of a symbol.

What has remained the same?

All the focus is usually on what has changed, but it worth considering where there are similarities. There continue to be a number of options for the stress–strain relationships for concrete, and the option of a simplified, rectangular stress block remains, although the depth of the stress block is slightly different.

Various options for analysis remain, including elastic methods, elastic analysis with redistribution, plastic analysis and non-linear behaviour. The principle that plane sections remain plane is also used.

The load arrangements used in the UK can continue to be used, i.e. maximum hogging is determined from the full load on every span, and maximum sagging is found by checking alternate spans loaded. Note however that the permanent action partial factor should be the same in every span.

There is guidance on the effective length of members and the design moment can be taken at the face of the column, not the centre.
The principle of using span-to-depth rules to control deflections remains.

Many of the detailing rules for particular elements remain the same, although there are some slight variations. For robustness, the rules for tying have not changed except that the design vertical tie force may be slightly different.

**Will there be savings?**

It is likely that there will be savings in materials especially in the longer term once designers are familiar with the new codes. These potential savings come from a number of sources. Depending on your perspective they can be viewed as an erosion of safety factors or a result of our increased knowledge.

Some of the savings arise from the combinations of actions in Eurocode. With the reduction for permanent actions down to 1.35 or even 1.25 from 1.4, and the variable action partial factor reduced to 1.5 from 1.6 there are savings of 5% to 10% on the loads applied to structures at the ultimate limit state. At the serviceability limit state there is a reduction in the effective partial factor for variable actions, which can be as low as 0.3 compared to 1.0 with existing standards. Designers should of course ensure that this reduction will still provide a building or structure that will meet the client’s requirements – serviceability limit states are advisory not mandatory.

Within Eurocode 2 itself the key savings come from the use of the variable strut inclination method for the design of shear reinforcement, which can reduce the number of shear links required.

There are a couple of areas where the Eurocode 2 could lead to more materials being used – more cover is often required for internal situations, mainly to allow appropriate fixing tolerances and more punching shear reinforcement may also be necessary.

Overall, the general opinion is that Eurocodes will lead to more efficient concrete structures and the savings over current practice will be 5% to 10%.

**What resources are available?**

The Concrete Centre and other industry bodies have produced a number of resources to assist the engineer.
The Concrete Centre resources include a series of ‘How to …’ guides, which are now available as books. Each guide gives a brief overview of a particular topic and describes what the Eurocodes require and how to carry out the design checks. They are succinct and enable the designer to confidently tackle the design of particular elements through the use of flow charts. They include derived expressions and design aids where these are required to carry out designs.

**How to guides:**
- Introduction
- Getting started
- Slabs
- Beams
- Columns
- Foundations
- Flat slabs
- Deflection calculations
- Retaining walls
- Detailing
- BS 8500 for building structures
- Structural fire design

The *Concise Eurocode 2* is designed to be an easy way for a designer to find their way into the code. The essential clauses are given along with the UK national annex values and clear references to the original clauses. There is also useful commentary, derived expressions and design aids.

The *Concise Eurocode 2 for bridges* is a similar publication for bridge engineers and is particularly useful as a starting point as it enables the designer to see at a glance what the code requires rather than deciphering it from Part 1.1 and Part 2 of Eurocode 2. The UK national annex values are included and clearly distinguished as are sections from the published documents (PDs).

The *Concrete Buildings Scheme Design Manual* is a handbook intended to assist candidates for the Institution of Structural Engineer’s chartered membership examination, and has recently been updated to incorporate Eurocode 2. It includes quick design methods and design aids that have been prepared specifically for Eurocode 2 and which will be useful when preparing preliminary designs to Eurocode 2.

*Economic Concrete Frame Elements* has also been updated to suit Eurocode 2. It is intended to assist in the rapid sizing of typical elements for initial designs,
and includes tables and charts for a variety of concrete elements including reinforced concrete, precast concrete and post-tensioned elements.

Properties of Concrete for use in Eurocode 2 provides engineers with a greater knowledge of concrete behaviour so that they can optimize the use of material aspects of concrete in their design. A series of worked examples have been prepared and will be published. These cover the analysis and design of typical elements. They are intended to show all the checks that should be satisfied for those elements, including detailing.

There are a number of other publications available from other organizations. British Precast has produced two companion guides specifically for precast concrete products entitled Precast Eurocode 2: design manual and Precast Eurocode 2: worked examples. The Institution of Structural Engineers has produced the Manual for the design of concrete building structures to Eurocode 2 (Green book) and Standard method of detailing structural concrete. Thomas Telford has published Designers guide to BS EN 1992-1-1 and BS EN 1992-1-2 and Designers guide to BS EN 1992-2.

When should I start using Eurocode 2?

In June 2008, BSI declared that BS 8110 was obsolescent. According to BSI, a declaration of obsolescence indicates the standard is not recommended for use in new ‘equipment’ but needs to be retained for the servicing of existing ‘equipment’ that is expected to have a long working life. For ‘equipment’ read ‘structures’.

BSI plans to withdraw BS 8110 and other structural concrete design codes on or about 31 March 2010. ‘Withdrawn’ indicates that a standard is no longer current and has been superseded by another standard or is no longer relevant to industry. It will also no longer be supported by a committee, which means that it will not undergo a five-year review. The standard is not necessarily unsafe, but will increasingly become outdated and therefore not current best practice.

The implication is that Eurocode 2 should be the concrete design standard for use in the UK, and it is expected that designers will move over to using it. And with the many resources available to make the transition as easy as possible, there is no reason to feel daunted.