The essential guide to Eurocodes transition

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Contents

Foreword

Professor John Roberts, Principal, Technical Innovation Consultancy

Structural Eurocodes – Frequently Asked Questions

View from the industry – benefits, threats and UK plc’s state of readiness

Chris Hendy, Atkins plc

Complete Eurocode listing

Key aspects of the Eurocodes

Eurocode: Basis of structural design

Professor Haig Gulvanessian CBE, Civil Engineering and Eurocode Consultant

Eurocode 1: Actions on structures

Professor Haig Gulvanessian CBE, Civil Engineering and Eurocode Consultant

Eurocode 2: Design of concrete structures

Owen Brooker, The Concrete Centre

Eurocode 3: Design of steel structures

David Brown, Associate Director, Steel Construction Institute

Eurocode 4: Design of composite steel and concrete structures

Dr Stephen Hicks, Manager Structural Systems, Heavy Engineering Research Association, New Zealand

Eurocode 5: Design of timber structures

Arnold Page, BSc, BD, MIWSc. Structural timber engineering consultant

v
The essential guide to Eurocodes transition

Eurocode 6: Design of masonry structures
   Professor John Roberts, Principal, Technical Innovation Consultancy

Eurocode 7: Geotechnical design
   Andrew Harris, Director and Dr Andrew Bond, Director, Geomantix Ltd.

Eurocode 8: Design of structures for earthquake resistance
   Edmund Booth, Consulting Engineer

Eurocode 9: Design of aluminium structures
   Phil Tindall, UK Technical Director (Bridges), Hyder Consulting

Annex A. Design of an LVL garage beam conforming to BS EN 1995-1
   Arnold Page, BSc, BD, MIWSc. Structural timber engineering consultant
Structural Eurocodes – Frequently Asked Questions

1 What are Eurocodes?

Structural Eurocodes are a set of harmonized European standards for the design of buildings and civil engineering structures. There are 10 Eurocodes made up of 58 parts that will be adopted in all EU Member states.

In the UK, they will replace over 50 existing British Standards that are due to be withdrawn on 31 March 2010 when full implementation of the Eurocodes will take place.

Eurocodes are a recommended means of giving a presumption of conformity to the essential requirements of the Construction Products Directive for products that bear CE Marking, as well as the preferred reference for technical specifications in public contracts.

Eurocodes cover the basis of structural design, actions on structures, the design of concrete, steel, composite steel and concrete, timber, masonry and aluminium structures, geotechnical design and the design of structures for earthquake resistance.

2 How do I use Eurocodes?

Eurocodes are designed to be used as a suite of documents, which means that for most projects more than one code will be needed e.g. BS EN 1990 Basis of Structural Design is always required.

In addition, Eurocodes are designed to be used with a national annex, which is available separately but is essential for compliance with the code.
Other documents required for using Eurocodes are the so-called Non-Contradictory Complementary Information (NCCI) documents. The status of these documents can vary. As the name suggests they provide supplementary material, that may be useful, but are not always essential for compliance with the Eurocodes.

Other documents include Execution Standards, which provide requirements for execution of structures that have been designed in accordance with Eurocodes.

3 What are national annexes and how do I use them?

In order to allow for the variety of climatic and other factors across the European Union each Member State may produce a national annex for each of the 58 Eurocode parts.

This will include

- Alternative values
- Country specific data (geographical, climatic, etc.)
- Alternative procedures.

It may also contain:

- Decisions on the application of informative annexes
- References to Non-Contradictory Complementary Information (NCCI).

Where a national annex is published it is essential to use it to comply with the Eurocode.

Where no national annex is available or no Nationally Determined Parameters (NDPs) are chosen the choice of the relevant values (e.g. the recommended value), classes or alternative method will be the responsibility of the designer, taking into account the conditions of the project and the National provisions.

NOTE: there will be no national annex to BS EN 1998-3 in the UK.

For information and to purchase national annexes applicable outside the UK contact BSI Distributor sales on 020 8996 7511 or email Distributor.Sales@bsigroup.com.
4 What are Nationally Determined Parameters?

The foreword of each Eurocode states that it recognizes the responsibilities of regulatory authorities in each Member State and protects their right to determine values related to regulatory safety matters at a national level where these continue to vary from State to State.

Accordingly, each Eurocode contains a number of parameters which are left open for national choice, called Nationally Determined Parameters (NDPs). The NDPs account for possible differences in geographical or climatic conditions, or in ways of life, as well as different levels of protection that may prevail at national, regional or local level. Recommended values for the NDPs are also provided in the Eurocodes.

5 What are NCCI and how do I use them?

Non-Contradictory Complementary Information (NCCI) are documents that the National committees consider useful for assisting the user to apply the Eurocode. They are not essential for compliance with the Eurocode but may provide background material or other guidance.

They have been approved by the BSI Committee and are usually listed in Clause NA.4 of the national annex.

This does not mean that all NCCI documents are produced by BSI however. They are not necessarily British Standards and may be published by other organisations.

6 What are Execution Standards and how do I use them?

These documents have been produced in support of the Eurocodes and are applicable to designs in accordance with the Eurocodes.

The Masonry Eurocode includes its own execution part (BS EN 1996-2) but other areas such as Concrete, Steel, and Geotechnics have separate documents, outside the Eurocodes suite, dealing with execution and workmanship.
7 How will Eurocodes be maintained and developed?

Eurocodes will be maintained and developed by the CEN/TC250 committee. Their responsibilities will include:

- Correction of errors
- Technical and editorial improvements
- Technical amendments with regard to urgent matters of health and safety
- Resolution of questions of interpretation
- Elimination of inconsistencies and misleading statements.

They will also approve any corrigendum (e.g. removal of printing and linguistic errors) or amendment (e.g. modification, addition or deletion of specific parts), as appropriate.

In addition, future editions of the Eurocodes, such as new annexes or parts and eventually new Eurocodes will be needed to include guidance reflecting new European Union policies, innovative design methods, construction techniques, new materials, products and the like.

8 What are the benefits of using the new Eurocodes?

- They will facilitate the acquisition of public sector contracts
- They will facilitate the acquisition of European contracts
- They are among the most advanced technical views prepared by the best informed groups of experts in their fields across Europe
- They are the most comprehensive treatment of subjects, with many aspects not previously codified now being covered by agreed procedures
- They provide a design framework and detailed implementation rules which are valid across Europe and likely to find significant usage worldwide
- They provide common design criteria and methods of meeting necessary requirements for mechanical resistance, stability and resistance to fire
- They provide a common understanding regarding the design of structures between owners, operators and users, designers, contractors and manufacturers of construction products
- They facilitate the marketing and use of structural components and kits in EU Member States
- They facilitate marketing and use of materials and constituent products, the properties of which enter into design calculations
• They enable the preparation of common design aids and software
• They increase competitiveness of European civil engineering firms, contractors, designers and product manufacturers in their global activities.

9 Have all of the Eurocodes been published?

Yes, BSI has now published all of the harmonized codes and national annexes. The British Standards referred to in Part A of the Building Regulations will be withdrawn on the 31st of March 2010 and be replaced by a new, more technologically sophisticated set of British Standards – the Eurocodes.

10 What happens to the standards I currently use?

Following publication of a European standard, BSI is obliged to withdraw conflicting standards i.e. those within the same scope and field of application as the European standard. Where the national standard is not in a one-to-one relationship with the European standard, the national standard will be amended or revised to delete the conflicting requirements and to reflect the changed scope.

Withdrawn documents are still available and remain in the BSI catalogue for historical information purposes but a BSI committee no longer maintains withdrawn standards. That means that there is no 5-year review when a committee considers the currency of a standard and decides whether to confirm, revise or withdraw it.

11 What happens if I continue to use the old British Standards?

BSI committees have already stopped updating the British Standards to be withdrawn on the 31st of March 2010, so designers need to be mindful of insurance and liability issues if they continue to use them.

The new standards will become the preferred means of demonstrating compliance under the Public Contracts Regulations 2006 and the Construction Products Directive.
12 Is there a legal or insurance-related risk arising from continuing to use the old British Standards?

In any legal proceedings relating to structural design, the courts and other dispute-resolution forums will refer to Eurocodes – the state-of-the-art standards – to reach their decisions. Continuing to use withdrawn standards could put structural designers and their insurers at increasing risk.

There is a risk that with a dual system engineers will use codes to suit themselves and this could introduce further confusion and risk.

13 Which projects use Eurocodes?

The choice of which standards to use will be influenced by EU Directives such as those on public procurement and construction products, which are enacted in the UK as the Public Contracts Regulations 2006 and the Construction Products Regulations 1991 respectively. As such, most UK public sector organizations, utilities and product manufacturers intend to use Eurocodes for all new designs after April 2010.

The Highways Authority (England Wales and Northern Ireland) will expect new designs to be in accordance with Eurocodes after March 2010. The Highways Authority requirements will be described in an Advice Note (an IAN) which will be published shortly. The actual standards to be used on a project will be defined in the AIP (Approval in Principle) document for each contract.

Network Rail will require new work from March 2010 to be in accordance with Eurocodes.

14 Has Eurocode implementation been held up by the delay to the revision of Approved Document A?

A revision to Part A to update the referenced standards has been delayed for unrelated reasons and CLG remains fully supportive of the new British Standards.

There is nothing to stop designers using British Standards cited in the Regulations, it is ‘legally permissible’ to use them, though they should be aware of the comments in Q12.
15 Many engineers are not ready for the new British Standards, why does BSI not postpone withdrawal?

Both BSI and the Government have a legal obligation to meet the agreed date for Europe-wide implementation of the Eurocodes (i.e. 31 March 2010). The CEN agreement to create and apply harmonized standards is made between European governments and then delegated to their National Standards Bodies.

16 How can I purchase Eurocodes?

Eurocodes are published and sold in each country by the National Standards Body and in the United Kingdom can be purchased from BSI at http://shop.bsigroup.com/eurocodes.

17 What kind of guidance on Eurocodes is available from BSI?

**Eurocode core documentation**

BSI has published all 58 Eurocodes with national annexes, associated NCCI and PD. See the Eurocodes website for more information http://shop.bsigroup.com/eurocodes.

**New online managed collection**

BSI has recently made available a managed PDF collection of the full set of Eurocodes and national annexes. More information can be requested at http://shop.bsigroup.com/eurocodesmanagedcollection

**Commentary, guidance, master classes, conferences**

BSI has designed a series of master classes, publications and an annual conference on key Eurocode themes covering key design materials such as concrete, steel, timber.

Further information can be received from http://shop.bsigroup.com/eurocodes
View from the industry – benefits, threats and UK plc’s state of readiness

Chris Hendy, Atkins plc

The Eurocodes are widely regarded as the most technically advanced suite of structural design codes available internationally. Why then is it often perceived that progress towards their adoption has been slow in the UK?

There is undoubtedly still some resistance from pockets of the UK structural community. Part of the inertia comes from the fact that the UK has extremely good British Standards already. For example, BS 5400-3 is widely considered to be the most comprehensive steel code of practice in the world but few would describe it as the most economic. Some in the UK argue that the Eurocode rules go too far and are, in some isolated cases, unsafe. There is however no evidence of this, particularly when the UK national annex has in a few places tightened up requirements. Arguments that the Eurocodes are unsafe because they give different answers to previous British codes are simply unsound and in places the British Standards are far too conservative and are increasingly being shown to be so.

Other resistance stems from the perceived effort involved in the changeover. The Eurocode awareness seminars that have been held over the last few years may potentially have been counter-productive. They have been intended to reassure, whilst at the same time demonstrate there is work to do. In some cases, pointing out a long list of differences in practice has made the process of adoption appear more daunting than perhaps it really is.

While there may be some resistance from within industry, BSI and the Highways Agency are actively driving implementation. The speed of production of national annexes has been on a par with or better than the progress made by much of mainland Europe. In addition, an increasing number of consultants
are using Eurocodes to form the basis of departures from standards in the assessment of existing structures because they can improve predicted load carrying resistance.

The state of readiness of industry bodies, software houses and institutions is also excellent by comparison with our other European counterparts. The Concrete Centre and Steel Construction Institute have produced, and continue to produce, much guidance and training material. Many of the big software houses are on top of software upgrades, waiting only for final national annexes to finalize releases. The ICE and IStructE are running seminars and training and publishing a comprehensive set of designers’ guides to the various Eurocode parts.

Readiness amongst designers is however more patchy. Some of the big consultants have strategies in hand for helping their engineers to make the transition. Atkins for example has rolled out a series of four-day training courses to 60 ‘Champions’ across the UK and ensured that all other staff have received the same training via a cascade from these Champions. Other companies are planning or have executed similar strategies. However, a significant number of companies are only just starting to consider the issue. There are good reasons to take the change seriously and act quickly. Some of these are discussed below. Most relate to the need to remain competitive.

Steel design

The rules given in the Eurocodes reflect modern research and bring together steel design practices from around Europe. Therefore, for bridges, for example, there is a significant change to the requirements set out in previous UK practice through BS 5400-3. Some typical examples include:

- **Class 4 beams with longitudinal stiffeners** – these are treated in the same way as beams without longitudinal stiffeners in EN 1993, unlike in BS 5400-3 where a completely different approach to calculation was employed involving checking individual panels and stiffeners for buckling in isolation. This allowed little load shedding between components and a single overstressed component could govern the design of the whole cross-section. In EN 1993-1-5, this does not happen and it is the strength of the whole cross-section which is important.

- **Shear–moment interaction** – EN 1993 produces a more economic check of shear and moment interaction than does BS 5400. There are various
reasons for the improvement in economy but the main gain relates to bridge
girders for which recent non-linear parametric studies have shown little
interaction between shear and bending for Class 3 and 4 cross-sections,
and this is reflected in the shape of the interaction curve in EN 1993-1-5
• **Web transverse stiffeners** – The design requirements for web transverse
stiffeners, provided to enhance shear resistance, are much less onerous
than those of BS 5400 and themselves have still been shown to be
conservative [1].

Various pilot studies were conducted for the UK Highways Agency to gauge
the difference in resistances overall between BS 5400-3 and EN 1993 and
hence measure the differences in expected materials costs. The conclusion
was that if the simple application rules were followed, steel bridges with
cross-sections in Class 1 and 2 throughout would require very similar quan-
tities of materials for both codes. Where the bridge was more typical, with
cross-sections in Class 3 or 4, a typical reduction in materials of around 10%
was expected with EN 1993. However, if more advanced analysis techniques
are used, such as non-linear analysis, much greater reductions can be achieved.

**Concrete design**

The rules developed for concrete design also reflect more modern research
and reflect the modern use of higher grades of concrete. The formulae given
in the Eurocodes use significantly higher concrete strengths than previous UK
practice; C70/85 for bridges and C90/105 for buildings. The UK national
annex however places a limit on cylinder strength in calculations of 50 MPa
for shear due to concerns over the validity of the equations with high strength
concrete, particularly those with limestone aggregates.

As with steel design, UK designers can expect to find some differences in
resistances between codes. Some typical examples include:

• **Resistance to bending and axial force** – The use of a design reinforcement
stress–strain curve allowing for strain hardening in EN 1992 can lead to
around 7% greater bending resistance with Class B reinforcement than is
obtained with BS 5400-4 where consideration of strain hardening is not
permitted. Greater increase is obtained with Class C reinforcement which
is more ductile.

• **Shear resistance** – Where there are shear links included in the design,
the approach in EN 1992 differs from that in BS 5400-4 and leads to a
potential large increase in economy for reinforced concrete beams. Unlike the BS 5400 truss model employed which has a fixed truss angle of 45°, the truss angle in the Eurocodes can be varied between 45° and 21.8° resulting in up to 2.5 times more resistance provided by the links. This has to be balanced by a potential increase in longitudinal reinforcement where this reinforcement is curtailed, but the designer has far greater choice over where the reinforcement is to be provided and its total quantity.

- **Punching shear** – One significant additional requirement in the Eurocodes involves the calculation of punching shear resistance allowing for the interaction with coexistent bending moment transmitted at the same time as the shear load. A typical example is a pad foundation supporting a column. This is one area where Eurocode 2 produces a lower resistance typically than did BS 5400-4.

### Increased use of finite element analysis

The use of finite element (FE) analysis will increase in the UK with the introduction of the Eurocodes as they provide codified rules for the use of both elastic and non-linear analysis which were not previously covered by UK codes; they were not prohibited but approval could be a long process with no guarantee of acceptance. Additionally, the format used in the Eurocodes (particularly steel) often facilitates the use of FE models and, in some situations, using an FE model is the most economic method both in terms of design cost and in terms of material costs.

Designers will need to embrace these analysis methods to remain competitive. FE analysis can give a very accurate representation of the true behaviour of the structure, but only if the assumptions made accurately represent this behaviour. As such, results can be either unsafe or overly safe if the assumptions are incorrect. Some examples of uses that are likely to become common are set out below, together with some discussion on possible pitfalls.

Linear elastic FE analysis is attractive because it permits the principle of superposition to be adopted; influence surfaces can be generated for the effect to be investigated and the results of different loadings may be combined. Elastic finite element modelling is appropriate for calculations on fatigue stress and serviceability where it is desirable for materials to remain elastic, but may be very conservative for predicting ultimate strength where plastic redistribution is possible after first yield. In the Eurocodes, particularly EN 1993, elastic
critical buckling analysis will be increasingly used to determine slendernesses for buckling directly from the computer.

Elastic critical buckling analysis is particularly useful for analysing the construction condition of paired beams before the concrete is poured to make them composite. The slenderness can be determined directly from the elastic critical moment, $M_{cr}$, according to

$$\lambda_{LT} = \sqrt{\frac{W_{y}f_{y}}{M_{cr}}}$$

This is quick and easy to do and it is common for the Eurocodes to give significantly greater resistance than BS 5400. Figure 1a shows the critical mode representing global instability of a typical pair of cross-braced beams (the lateral buckling referred to in the code) but this was the twentieth mode produced by the computer; there were numerous lower local buckling modes of the form shown in Figure 1b which could safely be ignored as they were included elsewhere in the codified section properties for the beam. Reference [2] contains an example where a 53% greater ultimate resistance against buckling was produced using this EN 1993 approach rather than BS 5400-3. The analysis of arches also lends itself to the use of elastic critical buckling analysis in a similar manner where determination of the buckling slenderness via an effective length would otherwise be imprecise and necessarily conservative.

Non-linear analysis is the most advanced calculation procedure now permitted by Eurocodes. When performed correctly, non-linear analysis of structures can get very close to the true resistance. This is especially true of steel structures where the ultimate behaviour of steel can be very accurately represented in computer models – Numerical validation of simplified theories for design rules of transversely stiffened plate girders [1] covering transversely stiffened plate girders provides a good example. The accuracy of reinforced concrete models is less uniform; predominantly flexural behaviour (such as pier second order analysis shown as follows in Figure 2) is well modelled but more complex behaviour requiring prediction of reinforced concrete behaviour under general stress fields is less well understood and predictions show more scatter from test results.

The paired beams above provide an example of the further reserve of strength than can be obtained by using a non-linear model. For the same example, non-linear analysis gave 99% more ultimate resistance than did the simplified approach in BS 5400-3. The reasons for this increased resistance are discussed in Lateral buckling of plate girders with lateral restraints [2].
Buckling of slender piers by non-linear analysis can also bring significant savings in reinforcement compared to simplified code formulae, such as those in BS 5400-4. A typical example was the piers of the Medway Bridge [3]. The rules for non-linear analysis in EN 1992, including imperfections and material properties, were employed in the design after the initial reinforcement tonnage produced in accordance with BS 5400 was found to be excessive.
The pier shown in Figure 2 was analysed twice; once with 32 mm diameter reinforcement (T32) and again with 40 mm diameter (T40). The deflections shown were for:

- uncracked linear elastic analysis;
- second order uncracked elastic analysis;
- cracked second order analysis with T32 reinforcement;
- cracked second order analysis with T40 reinforcement.

The non-linear analysis resulted in a saving of reinforcement of approximately 60% compared to the UK design code.

There is little guidance available on the use of FE which makes experience in the field very important for successful modelling. The encouragement to use FE modelling by the Eurocodes is likely to lead to more inexperienced designers using it as a routine design tool. Engendering the need for checking strategies in these engineers is therefore extremely important and this can be difficult where the modelled behaviour is complex. Contrary to what many designers believe, the availability of software packages to perform these analyses requires a much greater degree of structural understanding, not a lesser degree, in order to check the model is performing satisfactorily. The example above of elastic critical buckling in paired beams is a case in point; the designer

![Figure 2. Second order analysis of slender piers](image_url)
should have a strategy for verifying that the buckling modes produced are realistic and their eigenvalues are the right magnitudes. Standard textbook formulae could, for example, be used to approximate and check the critical stresses for the local buckling modes. A strategy for managing this change needs to be in place in design offices.

The above discussions set out some good reasons to embrace the change quickly. Designers who are not prepared face a risky transition period. The introduction of Eurocodes will provide a common set of design codes for use across Europe and, as considered below, in a number of countries outside Europe. Apart from a unique national annex (which can provide very limited information and will thus be very easy to assimilate by foreign competitors), a design done in the UK will follow the same set of rules as one done elsewhere in Europe. This will facilitate competition by UK designers across a wide range of countries but, of course, the reverse will also be true. If we are slow to adapt in the UK, others will not be and this brings potential threats to our industry.

The threats will not only come from within Europe. Countries with an existing reliance on, or close link to, British Standards are either already committed to adopting Eurocodes (e.g. Malaysia and Singapore) or are weighing up the benefits of adopting them (e.g. Hong Kong). In addition, training is starting in these countries. For example, the Institution of Engineers Malaysia commissioned Atkins to run a two-day Eurocode concrete bridge design training course for 85 delegates in Kuala Lumpur in September 2007, then commissioned another for steel design in March 2008 and has booked subsequent courses. At the time of writing there is no similar-scale external training taking place in the UK in bridge design. These countries may take a keen interest in UK opportunities.

The introduction of Eurocodes and the increased technical sophistication they bring is timely given the growing importance of the sustainability agenda and the drive for leaner construction. Many of the basic application rules in the Eurocodes lead to a modest but significant improvement in economy compared to existing British Standards. In many cases, this is derived from more recent research and testing. However, designers that follow the more complex methods of analysis permitted by the high level principles, such as non-linear analysis, may find very considerable improvements in economy. This will be the case, for example, for slender concrete piers or slender steel panels.
So to return to the original question, we shouldn’t consider that the performance of UK plc in adopting Eurocodes has been sluggish. We should however recognize that the Eurocodes bring both opportunities and threats, and so to maximize the former and mitigate the latter now is the time to step up our preparation activities.

References