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Those of us looking forward to the London Olympics in 2012 have first to negotiate the pressing issue of incorporating Structural Eurocodes into everyday design practice, writes Dr Andrew Bond

AS OF today, 42 of the 58 Eurocode parts can be purchased from British Standards Online (www.bsonline.bsi-global.com) and the remaining 16 parts are due out anytime soon. The UK National Annexes to accompany these codes will appear over the next 18 months, so that by 2009 everything will be in place to design structures – in concrete, steel, timber, masonry, and aluminium – to engineering rules and principles that are common throughout Europe.

For structural engineers, the changes required to existing practice are relatively minor. As Chris Hendy, head of bridge design and technology at Atkins has said,[1] the impact of Structural Eurocodes can be summed up as: "Same principles, different rules."

However, for geotechnical engineers, whose practice has been far less codified than in other sectors, the introduction of Eurocode 7[2] represents a marked change in UK practice.[3] The impact can be summed up as: 'Same rules, different principles'.

So, how can engineers prepare for the day when an irresistible force (Structural Eurocodes) meets an immovable object (our natural reluctance to alter existing design practice)?

> **"For geotechnical engineers, whose practice has been far less codified than in other sectors, the introduction of Eurocode 7 represents a marked change in UK practice"**

1. EMBRACE LIMIT STATE DESIGN

The Structural Eurocodes are firmly based on limit state principles – each design must be verified for a range of ultimate limit states (ie, situations involving the safety of people and/or the structure) and a range of serviceability limit states (ie, situations involving the functioning of the structure, the comfort of people, and the appearance of the construction works). Limit state design has replaced the older concept of permissible stress design in most forms of civil engineering. Notable exceptions are geotechnical engineering and transportation engineering.[4]

Eurocode 7 finally commits geotechnical engineers to the limit state approach, bringing the design of the substructure into line with that of the superstructure. We should not underestimate the importance of this step – it offers the opportunity to analyse a building and its foundations as a single entity, without a conceptual barrier at ground surface.

2. EMBRACE PARTIAL FACTORS

Another key change that Eurocode 7 requires to our design practice is the introduction of partial factors. When I last counted, there were 112 partial factors to choose from in EN 1997-1 (with a further 34

n irresistible force
n immovable object

Publication of Eurocode parts to March 2007

correlation factors for pile design) – although a third of these are numerically equal to one and hence can be ignored. This is a major complication compared with the handful of lumped factors geotechnical engineers have traditionally used in the permissible stress approach.

But wait – there is more justification for partial factors than for lumped. Partial factors can take account of unfavourable deviations of loads from their anticipated values, unfavourable deviation of material properties from measured values, and unfavourable deviations in dimensions from those given on the drawings. Lumped factors do what they say on the tin – they just lump all these together. And worse – large lumped factors (for example, 3.5 on bearing capacity) attempt to limit settlement by mobilising a small proportion of the available bearing resistance. But why 3.5? Why not 3.8? Or 4.0?

In the 'limit state + partial factor' philosophy of the Structural Eurocodes, these issues are treated separately. Safety is ensured by avoiding ultimate limit states with partial factors applied to key unknowns; function is ensured by avoiding serviceability limit states with partial factors set to unity (ie, by looking at the anticipated behaviour of the structure).

3. MIND THE SUBSCRIPTS

To cope with 112 partial and 34 correlation factors, geotechnical engineers will need a greater degree of rigour in their calculations than has hitherto been the case.

Basic variables, such as actions, material properties, and geometrical dimensions, are converted from characteristic values to design values by the application of specific factors. Permanent (G), variable (Q) and accidental (A) actions are multiplied by γ_G, γ_Q, and γ_A. The soil's shearing resistance (tan φ), cohesion (c′), and undrained strength (c_u) are divided by γ_φ, γ_c, and γ_{cu}. Nominal dimensions (a_{nom}) are adjusted by ±Δa.

Effects of actions (eg, bending moments, shear forces, and prop forces) may be increased by partial factors γ_E if that is more sensible than factoring actions directly. Resistances (eg, bearing resistance, shear resistance) may be divided by partial factors γ_R.

Ultimate limit states are verified by demonstrating that effect of actions (E) are not larger than the structure's corresponding resistance (R). In Eurocode notation:

$$E_{d,dst} - E_{d,stb} \le R_d$$

Here, the subscript 'd' signifies design values (after factoring), 'dst' stands for destabilising, and 'stb' for stabilising.

The purpose of showing you this equation is to illustrate the simplicity of the fundamental requirements of Eurocode 7 and to recommend attention to detail when decoding the subscripts.

4. DEMAND A GOOD SITE INVESTIGATION

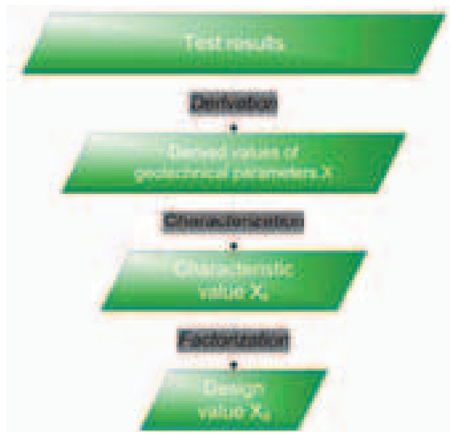
I know it. You know it. If only the client knew it. A good site investigation pays for itself many times over.

Eurocode 7 Part 2 – covering ground investigation and testing – helps engineers by establishing minimum requirements for geotechnical investigations that vary with the type of structure. Advice is given on the suitability for obtaining design parameters from various tests in various ground conditions.

The requirements for and definition of the 'ground investigation report' and 'geotechnical design report' will result in today's best practice becoming tomorrow's standard practice. Key features of these reports include an assessment of risk, discussion of known limitations of the results, and a plan of supervision and monitoring.

5. SELECT YOUR MATERIAL PROPERTIES CAREFULLY

Throughout the Structural Eurocodes, material properties are represented by what is termed their 'characteristic values'. For man-made materials, this characteristic value can be defined statistically as the 5% fractile of a normal distribution – a value we expect to exceed in 95% of cases.



This definition is difficult to apply to geomaterials. Soil properties are not as well-behaved as those of steel and concrete (ie, not normally distributed) and – to make matters worse – we rarely get sufficient data in one stratum to do the statistics properly. Consequently, Eurocode 7 redefines the characteristic value as 'a cautious estimate' of the value likely to affect the limit state. Understanding what a cautious estimate is will require re-education of the profession – as I discovered in a recent study,[5] interpretation of site investigation data can be more variable than the data itself!

CONCLUSION

'Comparing old and new codes of practice … [is] like comparing an old and a new pair of shoes; you become so familiar and comfortable with the old shoes that you compensate for their limitations … the new shoes will bring a period of discomfort before they are properly bedded in' [6]

Dr Andrew Bond is a UK delegate on the Eurocode 7 Committee, a former member of the UK's National Strategy Committee, and co-author of BSI's 'Guide to the Structural Eurocodes'. In November 2006, he ran a two-day Decoding Eurocode 7 course on behalf of the Singapore Building Authority.

Along with Andrew Harris and David Norbury, he is running a series of training courses in 2007 on 'Decoding Eurocode 7' (with separate days on introduction, design, and investigation) and 'Understanding Pile Design' – in Newcastle, Bristol, Birmingham, Glasgow, Belfast, Leeds (or Warrington), and London

Full details of these courses can be found at: www.geocentrix.co.uk/training

Acknowledgments

1 Bond AJ and Hendy CR (2006), Decoding the Structural Eurocodes, Geocentrix training course held at various locations in the UK.

2 British Standards Institution (2004), BS EN 1997-1: 2004, Eurocode 7 – geotechnical design, part 1 – general rules.

3 Nethercott et al (2004), National Strategy for Implementation of the Structural Eurocodes, Institution of Structural Engineers.

4 See the article on 'Limit state design' in Wikipedia (http://en.wikipedia.org/wiki/Limit_state_design).

5 Bond AJ (2007), Where do we draw the line? (in preparation).

6 Farrell ER (2005), Philosophy of the Eurocodes, Proc. Int. Workshop on the Evaluation of Eurocode 7, Trinity College, Dublin, 165-173.