Eurocodes and the geotechnical engineer

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Changing codes

EVERY PROFESSIONAL ENGINEER, and every engineering organisation, is progressively challenged by change. Opportunities arising out of research and technological development are made available in the marketplace with astonishing speed, not only in terms of hardware but also by virtue of the corresponding skills of graduate and postgraduate students, and of those engineers who choose to attend advanced courses. Of course, many firms which have taken a traditional view of their activities will feel threatened by such changes. It is particularly difficult for middle-aged managers to accept that a greater measure of responsibility can be devolved to the skilled graduate, especially when the outcome may be an apparently risky departure from past practice.

British codes of practice in civil engineering have traditionally permitted the engineer to transcend their advice should he feel competent to do so. Nevertheless, the arbitrary nature of many provisions — which may be generally conservative and on the average quite economic — makes it more difficult for the engineer to argue for the occasional sensible exception. It is therefore possible to imagine optimistically that a new generation of codes might free the engineer from unnecessary constraints by emphasising proper objectives and an acceptable methodology while eliminating references to specific guidelines which lawyers might interpret as 'rules'. It is equally possible, however, that new codes might become even more detailed and specific, offering less scope to the skilful designer, and possibly even forcing him into avenues which his professional judgement warns him are erroneous.

The EEC Directive

How, therefore, should soil and foundation engineers judge the development of Eurocodes, which will lead eventually to the publication by the EEC of Eurocode 7 on Foundations? Firstly, we should welcome the fact that the initial draft of EC7 is being prepared by a small committee of representatives of the various national societies of ISSMFE, including Dr. Brian Simpson from the British Geotechnical Society. By this means, the majority opinion of the membership of BGS on certain critical issues can be collected and reflected by our representative, which is a pre-requisite to their being incorporated in the final document. Three difficulties must be faced before this desirable objective can be achieved, however. Firstly, any idiosyncratically British point of view must be expressed in terms which other European groups can understand otherwise we will simply be ignored. Secondly, the point must be seen to be a matter of principle, of right versus wrong, rather than arising out of partisan interests. Otherwise, the discussion will degenerate into a sort of 'cod war', with some arbitrary political solution eventually emerging. Thirdly, the draft code elaborated in this way must eventually be acceptable to the EEC and to all member governments as a fair and workable basis for free competition within the Community. Otherwise, the bureaucracy will presumably attempt to rewrite EC7 itself.

These anxieties would fade, of course, if the draft EC7 were perfectly acceptable. What *are* the potential conflicts, and how seriously should we view them? Concern may arise partly out of statements made in the code itself and partly out of the nature of the legal framework within which the code is to be embedded. Regarding the latter, consider the following preamble to the Draft Council Directive by which the EEC proposes to achieve "the approximation (i.e. the drawing together) of the laws of the Member States relating to the construction codes":

> "Whereas provisions in force in the Member states have as their objective the safety, serviceability and durability of buildings and civil engineering works and whereas the rules applied by Member States to achieve this objective differ from one Member State to another;
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> "Whereas these differences hinder the provision of construction services between the territories of Member States and in particular impede the . . . . . . co-ordination of procedures for the award of public works contracts;
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> "Whereas these differences can be removed by the establishing of common rules . . . . .
>
> "Whereas it is necessary to establish an information procedure for numerical coefficients and loadings used by the Member States in the application of the common rules and to provide for the gradual establishment of common schedules of these numerical coefficients and loading;
>
> "The Council of the European Communities has adopted the following Directive".

The Directive itself has twelve articles, from which the following is a non-random sample:

> " 'Numerical coefficients' mean safety coefficients which are used to compensate for uncertainties and variabilities.
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> "Member States, when acting in the capacity of controlling authorities, shall not refuse, prohibit, impede or restrict the construction of buildings or civil engineering works which have been designed and constructed in conformity with the . . . . . . (Eurocode).
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> "Member States shall see to it that the construction and intended use of buildings or civil engineering works is not restricted or prohibited by the application by private persons or organisations, such as insurance companies or professional organisations, of rules or conditions which differ from those laid down (here) if they affect the provision of construction services between the territories of Member States.
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> "Member States shall . . . . . . inform the Commission of the values which it accords to numerical coefficients and loadings . . . . . . The Commission shall seek to harmonise these values . . . . . . not more than 5 years after the adoption of the . . . . Eurocode . . . . . .
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> "Where the special nature of the design or construction of a building or civil engineering works requires the application of rules supplementary to those laid down in the relevant Eurocodes in order to reach satisfactory levels of safety, serviceability or durability, a Member State may impose . . . (them). The Member State must advise the party submitting the project of the reason . . . . . . and of his rights of petition against . . . . . . (them).
>
> "The Member States shall bring into force the laws, regulations or administrative procedures which are necessary to comply with this directive within a period of 18 months from its notification . . . . . ."

The very clear message here is that the Commission believes that good design is a matter of selecting published safety factors to be used in the context of specified equations, and intends that any French or Greek engineer proposing to design or build works in London clay (for example) should be free to use the specified equations, and should not be disqualified simply because he has no previous experience of London clay. In particular, if a design follows the letter of the Eurocode, the presumption is that the end-product will be safe, serviceable and durable on foreign soil. The danger is, therefore, that the Commission failed to take professional judgement into account, other than to imply that any considerations which cannot be expressed arithmetically are probably of impure origin and tantamount to an attempt to restrain lawful trade. On the face of it, the legal framework erected for the Eurocodes has more the flavour of a document concerning permitted additives in euro-sausages, and the regulations necessary to ensure that the British do not arbitrarily adopt rules which restrict the free import of frankfurters under the pretext of public health regulations.

This makes it all the more important that the Eurocodes themselves spell out the basis of education, training and experience upon which good engineering is predicated. Any attempt by the drafters to create Eurocodes looking like design manuals for the amateur should be firmly resisted. Nor should engineers necessarily expect assistance from governments in this regard. If engineers themselves can, (free of charge), produce codes which apparently represent a detailed blow-by-blow account of how to design absolutely any-

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thing, then the Government will conclude that they were quite right not to take the profession too seriously. Why bother with engineers at all, if design is as easy as introducing the appropriate 'coefficients' into the stated equations? A microcomputer could do that.

The 'Head-code': Eurocode 1

Are these dangers being avoided? Consider first the draft of Eurocode 1: Common Unified Rules for Different Types of Construction and Material, which is intended to set out the philosophy which the other Eurocodes should adopt. Certainly the requirements that engineers be properly qualified, and that appropriate supervision be provided for a work-force which is itself sufficiently skilled, are spelled out carefully. It has been argued previously[1] that the concept of limit states is simply a format for declaring objectively the list of design requirements which must be met, and is therefore to be welcomed. The definitions of 'limit states and design situations' adopted by EC1 are:

> "The various ways in which the structure can cease to fulfil its function should be compiled. Each of these ways is treated as a *limit state*, which is a state in which one or other of the performance criteria governing the use of the structure is infringed.
>
> "When compiling limit states for design of particular structures or types of structures, it is necessary to consider various situations during their life, and to derive appropriate design situations. Among design situations to consider are those:
> (*a*) during construction
> (*b*) during use
> (*c*) during and after envisaged misuse or accident".

These definitions, and the ensuing classification of limit states into those involving collapse and those concerned with serviceability, should cause no problems for geotechnical engineers.

Problems do arise with later sections of EC1, however, as the following quotations may demonstrate.

> "A calculation model should be established for each limit state, incorporating appropriate basic variables. The following basic variables will be involved in most limit states:
> (*a*) actions
> (*b*) properties of materials
> (*c*) geometrical parameters".

At this point the geotechnical engineer may wonder how he is to deal with limit states which cannot in fact be calculated. Consider, for example, the settlement of footings on fluvio-glacial sand which may or may not contain peat lenses. Either the peat is beneath a footing in which case it is unacceptable, or it is not. Calculations are irrelevant and impossible. EC1 considers that all uncertainties in properties of materials can be dealt with by partial factors, multiplying the so-called characteristic value, on the assumption that the extreme values will be members of the same population as sampled values. The obsession with 'parameter uncertainty' at the expense of 'system uncertainty' has been criticised previously[2], and this remains unanswered.

The definition of 'characteristic value' in EC1 is as follows:

> "Properties of materials are generally represented by their characteristic values . . . . . . (which) can be presented as that value which has a prescribed probability of not being attained in a hypothetical test series taken from a homogeneous quantity of material . . . . . . Specified characteristic values should be ensured by adequate quality control."

The consequences of this definition are nothing short of dramatic for geotechnical engineers. The requirement is that a sufficient number of samples be taken from every identifiable sub-stratum to lead to a proper statistical selection of a 95th percentile. Presumably no member of EC1 had considered soil for a moment when they referred to 'homogeneous quantities of material'. Soil being rather less homogeneous than concrete would require an order of magnitude more samples to be taken before these sort of statistics could be applied. As every foundation engineer is well aware, however, the concrete designer presently relies on a quality control regime testing a volume fraction about $1/10^{3}$ whereas the geotechnical designer is lucky to receive samples amounting to $1/10^{6}$. EC1 therefore implies that we should be receiving about a thousand times more soil samples, in order that we can follow their particular analytical method.

Engineering, we were told at our father's knee, is the art of doing something for a penny which any fool could have done for a pound. It seems not to have occurred to EC1 drafters that the alternative of getting someone to test innumerable random samples, plot a probability density function, find a good number and then multiply it by 1.25 (or whatever the EC has designated the partial factor to be) is simply to ask an experienced engineer to produce an appropriate design value as economically as possible.

However, EC1 does not stop there, but goes on to invoke further partial factors, including an array of different values to cover all the anticipated load combinations, a factor to deal with the various consequences of failure, and a factor related to uncertainties in the validity of the whole approach (a large number, perhaps?).

There does seem to be just one escape route from this unworkable and anomalous rigmarole. In the commentary which accompanies the text of EC1 can be found the following:

> "In certain cases it may be appropriate to estimate a design value directly: thus the partial factor is implicit in this estimation".

Bearing in mind the degree of unquantifiable uncertainty in the assumption of a soil profile, let alone soil properties, the drafters of EC7 would have been well advised to declare at the outset that every soil design value should be estimated directly by an experienced engineer.

Eurocode 7: General Principles

EC7 (Foundations) is still in a much more provisional form than EC1 and the Draft Directive. The draft available in January 1983 refers to 10 chapters. Chapter 1 is entitled General Principles and defines the scope of the code and the user for whom it is written — "the qualified engineer with geotechnical knowledge appropriate to the project . . . . . . "

Chapter 1 then continues by defining three progressively more complex levels of Geotechnical Category which, it states, may demand correspondingly more advanced levels of site investigation, testing, and calculation. The first category dealing with simple structures such as "light buildings with a maximum design column load of 250kN and 100kN/m for walls, with no special requirements as regards settlement . . . . . " in the simplest circumstances geologically and geographically may, it is implied, not be subject to the full rigours of investigation and analysis. This apparently fails to take into account the fundamentally erratic nature of soil, and fails to make an equation between costs and benefits. The code might be taken to imply that it would be acceptable to build a £100 million housing estate with something less than a full site investigation, since each house was 'simple'.

If low-level investigations are specifically allowed by the Eurocode, it is reasonable to anticipate that some clients will demand them. The EEC Directive, quoted above, would strongly inhibit any corrective action being taken, even if any other engineer felt that the risk was unacceptable. The legal and insurance wrangles concerning work done 'according to the Eurocode' which later ran into trouble would be interesting, but the reputation of the profession would be further eroded.

Surely no professional engineer would spend his client's money on further tests or site reports when he had already formed the clear impression that the cost of further information outweighed the benefit of possessing it, whatever the project 'category'. The codification of 'Geotechnical Categories' amounts to an attempt to codify professional judgement. It cannot be done, and it is strongly prejudicial to the interests of both clients and engineers that it be attempted. All that is necessary is that the Eurocode confine itself strictly to what is generally known and accepted and that in the commentary, from time to time, it refers to matters being 'in the realm of professional judgement'. The procedures available for reducing risk can be listed, as can the risks themselves, but it is the privilege of the professional engineer to take the decision. His reputation bears the residual risk.

Verification of safety and serviceability

Chapter 2 is concerned with the methodology for the verification of safety and serviceability. Two methods are defined, "prescriptive measures" which eliminate limit states by the adoption of some appropriate conservative technology (e.g. the specification of sulphate-resistant cement in acid ground), and "calculation models" by which appropriate proportions and properties can be selected. A substantial advance is then achieved by discussing the calculations in terms of design values.

> "Each limit state may be studied directly by considering pessimistic values of parameters and other conditions, for which the calculations indicate that the limit state would just occur".
>
> "In order to ensure a sufficient degree of safety against the occurrence of any limit state, the variability, uncertainty and inter-dependence of these basic variables should be taken into account. Special attention must be paid to exceptional cases, particularly those involving uncertainty in water levels, geology, or stratification".
>
> "The values of the variables entered into the calculations are called 'design values' . . . . . . , the values adopted in the calculations should be such as to ensure that the occur-

rence of a more adverse set of values is, in practice, sufficiently unlikely . . . . . . Guidance on the selection of design values is given in this code, but the designer must always check that, in his opinion, the selected design values will achieve the aims stated here".

This excellent approach leaves the code able to offer any knowledge it feels is sound, while emphasising the responsibility of the engineer for taking the decisions. Unfortunately, the chapter then offers, as an alternative, the derivation of design values by the method of characteristic values and partial safety factors which, as explained previously, should be anathema to every professional ground engineer who wishes to retain his independence and integrity. The problem of identifying homogeneous zones of material from each of which a sufficient number of random samples can be taken to create the statistically valid characteristic values demanded by EC1, is not addressed. Nor is it explained why any committee should feel itself able to publish fixed partial factors by which these most expensive estimates are altered by the same amount in each case, notwithstanding that it is the engineer with the site investigation report who is in the best position to judge the risk of variability in ground conditions.

Every effort must be made to bring our European colleagues to an understanding of the invalidity of the approach centred on characteristic values. In particular, the drafters of Eurocode 7 must be freed from the philosophy of Eurocode 1, and permitted to create a code for geotechnical engineers which makes no mention either of characteristic values or of partial factors. Nor should it be acceptable to offer these concepts as an alternative unless the strict statistical safeguards specified by Eurocode 1 are adhered to.

If statistical techniques based on a controlled sampling system can be used to generate characteristic values, then one is vulnerable only to the inherent assumption that soil displays randomness within a homogeneous population. If, as indicated in the present draft of EC7,

> "The designer should select characteristic values such that, in his judgement, the probability in the field situation of a more adverse value relevant to the limit state being considered is not greater than 5%".

the profession is additionally vulnerable to being undercut by any sharp operator whose statistical judgement can be influenced by commercial pressures. The fudging of issues is never to be welcomed, but it is particularly damaging in legal documents: consider again the Draft Council Directive. And if the designer is to "use his judgement" in the selection of a value, what is the justification for multiplying his selection by a fixed partial factor of 1.25, or whatever. If I can be trusted to estimate 0.8 x by whatever means, then perhaps I might be equally capable of estimating x directly! Of course the designer must use his judgement to select design values. What the Eurocode must not do is to imply that any half-baked statistical method can be seen as an *alternative* to the accepted methods which geotechnical engineers have used successfully.

Technical details

Once the danger is avoided of attempting to take away the engineer's rights and responsibilities for decision making based on geotechnical consideration, it can be argued that detailed methods of testing and analysis can safely be included in a code. Of course, every formula is up-to-date only so long as no one is attempting to improve it, while the rate of progress in our understanding of soil problems is higher than ever. In most engineering disciplines these state-of-the-art methods and calculations are collated as technical appendices to codes, and are capable of speedy revision. It is high time civil engineers accepted this useful convention: the Eurocodes offer the opportunity, but the present draft of EC7 fails to grasp it as well as it might.

Instead, chapters on the procedures and calculations for shallow footings, piles, retaining structures, slopes, and construction control, contain a mixture of statements possessing various degrees of authority. The main text contains the list of issues to be considered, while the accompanying commentary offers various methods of calculation as "guidance". This is inferior to the use of Data Sheets since lawyers will wish to argue that a "commentary" offering "guidance" must offer an important insight into the intentions of the writers, and must therefore be seen as an extension of the code, within its legal framework. This would lead eventually to the merging of the two, and would set the whole weight of EEC and national bureaucracies against any change to any part on the grounds that it could cause a shift in relative national advantages.

Methods of calculation need not be politicised. If an analysis making certain assumptions leads consistently to the derivation of soil strength and stiffness parameters from a self-boring pressuremeter test, for example, then such a method should appear, or be referenced, in a technical appendix to the code. Other analyses using the methods of elasticity or plasticity to predict settlements or collapses based on appropriate soil parameters should also appear in the appendix. These objective methods and data sheets should be continually under review *by the profession*, and should be subject to alteration and deletion as new information arises. The code itself, the legal document ratified by the EEC and its Member States, should simply state what considerations are necessary, and should indicate that qualified engineers should be responsible for those judgements and decisions.

External relations: marriage or divorce?

British geotechnical engineers are under pressure from various quarters to amend their checking procedures so as to achieve compatibility with others. The production of new domestic codes of practice under the auspices of BSI has thrown into sharp relief the difference in philosophy between soil designers and such structural codes as CP110 for concrete. What is now emerging, however, is the understanding that many concrete designers are equally at odds with the philosophy of characteristic values and partial factors[3,4]. Those engineers at a recent well-attended Informal Discussion on the subject at the Institution of Civil Engineers heard a continuous catalogue of amusing paradoxes which emanated from the quasi-statistical treatment of concrete strength. The mood was that engineers usually came to sensible decisions *in spite of the code*, and that the main threat to normal practice came from those who appealed to the code rather than to common sense. Lawyers were sometimes mentioned in this connection.

There is no reason why professional structural engineers should continue to accept these constraints, and no reason whatever for geotechnical engineers to similarly shackle themselves on the spurious grounds of compatibility. On the contrary we can be of great service to our structural colleagues by demanding of *their* code-writers the "design situations" and "limit states" which they are addressing, and by refusing to conceive of anything other than "design values" of parameters chosen by the engineer. The paradox of CP110 is that many calculations proceed with negligible consideration of what set of physical circumstances are being considered. Try asking a structural engineer what loads could actually cause collapse.

We should not be discussing compatibility in terms of meaningless safety factors, but in terms of the inevitability of soil structure interaction. How frequently, these days, are foundation actions specified by means of a structural computer program which assumes an elastic skeleton with fixed feet? What response can we make when intermediate columns, for example, are supposed to carry an equal share of the overall shear forces but with negligible vertical thrust? Must we really respond by designing expensive foundations for insignificant members, simply because the structural engineer's computer is unaware that simple footings cannot carry shear force and bending moment unless they also carry thrust? Is it not our responsibility to refine and simplify our mechanical understanding of the behaviour of the ground until we are able to publish Data Sheets by which we can convince architects and structural engineers of the advantages of incorporating our methods into their calculations?

In the context of the EEC, we geotechnical engineers are equally under pressure and perhaps more at risk, since the drafters of the headcode EC1 have apparently been negligent of the potential impact of the policy they were making on our behalf. But the dangers of complacent insularity are just as great as those of being overwhelmed by foreign ideas. What is required is the capacity to adapt those new concepts which could prove useful in order to defeat those which would be damaging. This article has attempted to show that the two concepts of the design situation and the limit state may be used to attack the parasitic notions of the characteristic value and the partial safety factor which, together, threaten to replace independent professional judgement by a legally-backed standard formula. Our strongest allies may prove to be the statistical fundamentalists who have dictated these sections in EC1, and who might be coaxed into admitting that their logical deduction would be an insistence on a thousandfold increase in the number data points.

We will not find ourselves either misunderstood or accused of a partisan approach, if we simply champion the right and responsibility of the professional engineer to make decisions in the best interests of his client, and with regard to the public interest. Nor should the EEC feel that we are acting improperly if we only agree to a Eurocode which sets out per-

(concluded on page 31)

Eurocodes and the geotechnical engineer (continued from page 21)

formance criteria, and specifies the type of design situations which must be faced and the limit state modes which have been observed, for different types of construction. Indeed, the removal of all methods of calculation to an appendix of data sheets and references would enhance rather than detract from an objective description of the process of design and verification.

If the outcome of the meeting of the British Geotechnical Society on the 12th May 1983 were a clear opinion in favour of a technical appendix to contain data sheets which remained under the control of ISSMFE, and against any mention of characteristic values, partial factors, and geotechnical project categories, there is every prospect that the personal negotiations within the present drafting committee will lead to these principles being adopted in the first draft. Even should this prove less than completely satisfactory, BGS would thereafter be able to act as a focus for those engineers in the rest of Europe who share our concern, so that appropriate changes may be effected before the document becomes law.

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