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 it necessary to do so. Hence, 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, they 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 these means, the majority opinion of the membership of BGS on certain critical issues can be collected and reflected by our representative, which is a prerequisite 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. Second, the document 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 on a fair and workable basis for free competition within the Community. Otherwise, the bureaucracy will presumably attempt to rewrite EC7 itself.

These anxieties 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;"

"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;"

"Whereas these differences can be removed by the establishment 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 common rules and to provide for the gradual establishment of common schedules of these numerical coefficients and loadings;"

"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."

"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."

"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."

"Member States shall inform the Commission of the values which it accords to numerical coefficients and loadings. The Commission can then take its decision as to whether or not to impose these values ... not more than 5 years after the adoption of the Eurocode."

"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 in foreign soil. The danger is, therefore, that the Commission failed to take professional judgement into account, rather 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 basic safety, education, training and awareness which are the confidence 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 any indulgence 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...
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 it's made out to be? 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 follow. Central to 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 that the concept of a 'limit state', 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' stipulated 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 the possible 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, would 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 tabulated 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 to deal with limit states which cannot in fact be calculated. Consider, for example, the settlement of foundations. A bearing 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 assumption of 'systematic uncertainty' at the expense of 'systematic uncertainty' has been criticised previously, 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". So any geotechnical engineer who believes that such a structure would require an order of magnitude more samples to be taken before these sorts 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 1/10th whereas the geotechnical designer is lucky to receive samples amounting to 1/10th. EC1 therefore implies that we should be receiving about 100 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 to me that 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 coefficient is nominated as 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 impose further onerous 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 of factors). 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 shape of 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 1982 refers to five 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. And the lowest 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, if it is implied, not require a series of investigation and analysis. This appears to take into account the fundamentally erratic nature of soil, and fails to make an equation between costs and benefits. The implication must be taken to imply that it would be acceptable to build a £1 million housing estate with something less than a full site investigation, since each house was 'simple'.

If low-level investigations are specifically allowed, it would seem 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 engineers felt that the risk was unacceptable. The question 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 it is not professional engineers who would spend their 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' and 'partial factors'. Its 'practical Categorisation' 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. If there 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 that are listed, can as 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' and 'calculation 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 of materials are selected. Loading and loadings are then advanced 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, i.e. such that 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-

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ence of a more adverse set of val-
ues is, in practice, sufficiently un-
likely . . . . . Guidance on the selec-
tion of design values is given in this
code, but the designer must always 
check that, in his opinion, the select-
ed design values will achieve the 
aim of the project.
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 addition, 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 in-
tegritous intellectual environment. 
Inherent zones of material from each of 
which a sufficient number of random 
samples can be taken to create the statisti-
cally 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 engi-
neer with the site investigation report who 
is in practice 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 must be firmly fixed in the 
philosophy of Eurocode 1, and permitted 
to create a code for geotechnical en-
ngineers which makes no mention either of 
characteristic values or of partial factors. 
Nor should it be acceptable to these 
concerns to make a harmless concession 
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 displacements are normally 
homogeneous population. If, as indicated 
in the present draft of EC7,
"The designer should select char-
acteristic values such that, in his 
judgement, the probability in the 
field of the worst result being 
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 influ-
enced by commercial pressures. The judg-
ing of issues is never to be welcomed, 
but it is particularly damaging in legal 
documents: consider again the Draft Coun-
cil Directive. And if the designer is to "use 
his judgement" in the selection of a 
value, which 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 judgment, but it needs to be in the 
context of a larger body of statistical 
knowledge. 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 en-
ngineers have used successfully.

Technical details
Once the danger is avoided of attempt-
ning to take away the engineer's rights 
and responsibilities for decision making 
based on geotechnical consideration, it can 
be argued that detailed methods of test-
ing and analysis can safely be included in 
a code. Of course, every formula is up-to-
date only so long as no one is attempt-
ing to impose on him progress in our 
understanding of soil problems. In most engin-
eering disciplines these state-of-the-art 
methods and calculations are collated as 
technical appendices to codes, and are 
addressed to a considerable extent by 
structural engineers. Civil engineers accepted this useful 
convention: the Eurocodes offer the opportu-
nity, but the present draft of EC7 fails 
to grasp it as well as it might.
Instead, chapters on the procedures and 
calculation techniques for evaluating 
supporting 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 accompany-
ing 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 import-
ant insight into the intentions of the 
author, facts which therefore be seen as an 
extension of the code and thus the legal 
framework. This would lead eventually 
to the merging of the two, and would set the 
whole weight of EEC and national bureau-
cracies against any change to any part 
of the code, and that it could cause a 
shift in relative national advantages.

Methods of calculation need not be poli-
ticised. If an analysis making certain as-
sumptions leads consistently to the deriv-
a tion of soil strength and stiffness 
parameters, then it can be a sound 
engineering test, for example, the test should 
appear, or be referenced, in a tech-
nical 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 
be incorporated in the code. The key point 
says that methods and data sheets should be con-
tinuously under review by the profession, 
and should be subject to alteration and de-
letion as new information arises. The coda 
that makes the Eurocode anachronistic, 
that the Eurocodes must be treated as a 
legal document: that the structural en-
engineers have a right to demand that 
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 char-
acteristic value and the partial safety factor 
which, together, threaten to replace inde-
pendent professional judgement by a legal-
ly-backed standard formula. Our strongest 
diagnosis may be that these Eurocodes 
are written by lawyers who have interpreted 
these sections of 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 mis-
understanding the Eurocodes, or adopting 
an approach, if we simply champion the right 
and responsibility of the professional en-
geineer to make decisions in the best inter-
ests of his client, and with regard to the 
public interest. Nor should the EEC feel 
that only engineers who are prepared to 
only agree to a Eurocode which sets out per-

(continued on page 31)
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.