Geotechnical aspects of the use of computers in engineering : a personal view

I. M. Smith

Mr J. G. Parkhouse, *University of Surrey*

I have specialized for many years in stress analysis of structural components of all sorts, usually components thought to have integrity problems, and I am familiar with the problems of the interpretation of computer analyses which Professor Smith reports are of crisis proportions in geotechnical engineering. It is good that he has brought this problem to our attention, as I have been surprised how seldom engineers discuss the effects of the computer's rapid development on engineering.

21. A fluid-dynamicist colleague confirms that fluids problems are being tackled successfully by numerical methods. The Navier-Stokes equations seem to model fluid flow adequately. But then fluids do not fail, except perhaps when they cavitate. It does seem that failure is difficult to model. If this is so the geotechnical engineer has drawn the short straw because as Professor Smith writes 'a state of partial progressive failure is probably the norm for geotechnical constructions'. Those dealing with structures in other engineering disciplines are more fortunate, designing for loadings that are unlikely to occur using substantial safety factors. In these less demanding situations linear analyses followed by the application of empirical rules for integrity checking have resulted in generations of satisfactory structures. The rules have roughly marked out the boundaries within which failure is practically impossible. At present it is these rules and not the computer analyses that describe a way of guarding against failure in structures.

22. Other handicaps the geotechnical engineer suffers are the secondhand material he has to use, already damaged by previous use in past ages, and the lack of reliable material data. If metallurgists had only been able to obtain samples consisting of a handful of molecules extracted from microscopic boreholes they would not be the confident materials scientists they are today.

23. Professor Smith mentions 'new analysis' as the particular computer application that is giving rise to a crisis of confidence in geotechnical engineering. A crisis of confidence is an intelligent response to a dangerous situation, the situation in this case of inadequate modelling masquerading in such a novel sophisticated form as to improperly impress intelligent engineers. A temporary crisis of confidence is a good response provided it is followed by a sound analysis of the situation. What is at fault is not the power of the modern computer but imperfect understanding of both the structures being engineered and models of them. Engineers need to be encouraged to understand failure and to develop their theories of failure. When failure theories are as sound as the Navier-Stokes equations the computer's part in new analysis could probably be reclassified as another useful

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piece of data manipulation under Professor Smith's 'automation' heading, and the crisis of confidence will have disappeared.

24. Theories are important. Consider where we might be now if we were without the rapidly developing theory of fracture, begun by A. A. Griffith in 1920. Would we be trying to analyse the stress and strain fields around every crack tip and applying failure criteria to every element of material? Such unenlightenment, where it existed, could generate the sort of unrewarding computations that could lead to a crisis of confidence.

25. In 1981 I recognized a hierarchy in shape, form and material, a principle that I believe should be a part of the theory of structures. Since then I have been taking a critical look at the theory of structures to see how the hierarchical nature of shape, form and material can be included and to see if the theory is lacking in other ways. I have won the support of BP's Venture Research Unit who enabled me to come to Surrey to work on the development of the theory, in fact to do an inspection, maintenance and repair job on the theory of structures. The head of the Venture Research Unit calls me a theoretical engineer, by which he means someone who is in engineering theory. The concerns that Professor Smith expresses suggest to me that we need theoretical engineering, in that sense, on the principles underlying non-linear analysis of material failure.

Mr A. D. Moonasingha, Associate

Computer application *per se* does not constitute a new theory of geotechnical or any other engineering analysis—'computer automation has not added anything to the analytical process'. One aspect of efficiency in the computer is its coherent analysis of an engineering module or a system maintaining idealized continuity and interface interaction according to predetermined theoretical principles embodied in an analytical model, following the set path of a linear or dynamic program. The quasi-discretization process in the finite element retains the pertinent continuous medium of the body. Often what the computer does in engineering analysis is solve a very large matrix program. The computer is capable of churning out detailed results of a lengthy series of computations where the human can practically perform only a fraction of this, without resorting to simplified approximations, or would find too tedious. It is efficient in performing repetitive computations assimilating substitutive input data. With the aid of a filed program and information the computer can produce an answer or results output by responding to newly introduced data of the integral parameters. The computer can record dimensional parameters, process according to a predetermined instructional program and accomplish a mathematical or graphical solution.

27. Perhaps what the Author implies is that programs available for geotechnical analysis are not flexible, or are limited in the scope of depiction. Computer simulation of hydrological models also can be approximate; but can the computer be blamed for that? The computer provides a facility as a fast-acting processor and a vivid simulator to ease the accomplishment of imaginative mathematical tasks with economic and ergonomic objectives. The results of the computer analysis are as good as the postulation and depiction of the specific problem and the potency of the mathematical model and input data. The quotation 'when there are no concepts or when mathematical equations are not available, then use the finite element method' may be wrong as a doctrine, but rational as Dr Smith has quoted it.

28. Soils and rocks are two of the least homogeneous formations the engineers

have to deal with. Their sustenance is variable with the presence or movement of water and the long-term impact of loading. For these reasons usually geotechnics incorporate high safety criteria. Although a matter of chance, stable land formations apparently without these theoretical safety factors do exist.

29. Empirical methods furnish more realistic results than the stochastic methods. The versatility and limitations of empirical methods are obvious and vary with the field of engineering. When the variable parameters are dominant in the analysis (such as in water resources and transportation) stochastic methods dependent on empirical data and logistic mathematical models are necessary for design for the future, taking into account the trend and growth. Whether processed by the computer or not, these extrapolated, speculative analyses will provide only approximate results. To compensate for this, beside a conventional safety factor, a contingency provision has to be incorporated which will be controlled by the economic restraints. In hydrodynamics, physical models are often used for analysis due to their simulative expedience; an approach using a destructive timber model of analysis has been associated with a rash of breakwater failures.

30. The graduate trainees in some establishments are given the opportunity to gain broad experience in several departments. It is the widely believed view of the engineers that only a small amount of the theoretical knowledge gained during a civil engineering degree is directly used in one's profession in civil engineering. A large proportion of the trainee engineers are closely guided during the training periods, but some are left to find their way through planning, design and documentation of civil engineering schemes; besides there may be pressure to meet completion schedules, to furnish necessary information to other team members and any other associated personnel. The point is when it comes to application of advanced theories of civil engineering into complex projects of dynamics, stress analysis, or flow systems and the process plants, it is unwise and impractical for the graduate engineer to grapple on his or her own. Ironically many establishments either do not adopt these intricate processes or do not have suitable supervisory engineers to guide the graduate engineers inexperienced in these fields.

31. The common state of the art is simplified postulations and computer aided design. Paradoxically the computer aided design has partially removed the ideology of civil engineering as an application of civil engineering theories into practice; it has been replaced with adaptation to the computer and to information technology. It is not only simple for a civil engineer to adopt the computer and information technology: a technician can be trained to carry out many of the mundane computer aided designs and other tasks. The common usage of computers in civil engineering is different from the small-scale user practice of civil engineers who prepare their own programmes. It is suitable for a small proportion of civil engineers to grapple with the procedures of intricate computer analysis and information technology, but it cannot be a favourable norm for the civil engineering profession as a whole.

Dr Smith

Computers arouse strong emotions and a theme of the Paper was that, to a large extent, computers are acceptable in geotechnical engineering as long as their role lies in the general area of automation. The Author takes the more radical line that new analysis, properly conducted, leads to insight which can improve understanding and ultimately design.

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33. The thrust of UK research in geotechnical engineering is not in the direction of new analysis using computers. Examples were given in the Paper, and the Author has received a two-page document from the Science and Engineering Research Council headed 'Co-ordinated research programme in geotechnics' which does not contain the word 'computer'. It does contain the word 'database'. Recently, around 80 young UK researchers in geotechnical engineering met to discuss their work and exchange views. Their areas of interest were

- (a) small (usually not to scale) laboratory models—30%
- (b) centrifuge (usually scale) models—4%
- (c) field studies—22%
- (d) laboratory investigations of stress-strain-strength—34%
- (e) developing new analysis software—10%.