Beyond 2000 in Computational Geotechnics – 10 Years of PLAXIS International © 1999 Balkema, Rotterdam, ISBN 90 5809 040 X

On the future of PLAXIS

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1 INTRODUCTION

During the period from 1984 to 1994, when I was heading the PLAXIS-group at Delft University, I have written a series of memoranda to the Dutch Public Work Department. No doubt, my main interest was to maintain financial support for further development of the computer code. The first memorandum was a short note of only five pages. The second time, however, I did much better by producing 14 pages of dense writing with the title "Plan of Action for PLAXIS Development in 1989, 1990 and 1991". This memorandum came to birth on 17th July 1988. I remember that some readers found it too lengthy, which gave me an excuse for making later notes really short. No doubt the lengthy note of 1988 is full of thoughts and it is worthwhile publishing some of them on the occasion of this PLAXIS-Symposium in 1999, i.e. 11 years later. I will also seize the opportunity of adding some additional thoughts.

2 WHAT IS IT THE USERS WANT?

2.1 *Memorandum 1989*

Because of its many sea dikes and river embankments, the Netherlands have a special interest in geotechnical research. For making results of geotechnical research operational, we need computational geotechnics. New developments in the field of geomechanics lead to mathematical models, which will then be implemented in computer codes. If things go well one does not restrict this numerical work to a simple pilot-program, but extends it to a well-documented computer code. Unfortunately the costs of documentation and user-instruction are high and many pilot-programs do not grow out into user-oriented software. Especially in geotechnical engineering we have many pilot-programs and even some mature codes, but unfortunately not in the field of stress and strain analysis.

Hand in hand with the growing power of hardware and the increasing user-friendliness of office-software, geotechnical engineers will also put higher demands on the geotechnical software that they use. They will not only require high-performance with respect to the numerical simulations itself, but they will also desire computer codes that are easy to use. Hence we have to work both on the "inside" and the "outside" of the PLAXIS code.

2.2 *Comments 1999*

The still growing demand for the "outside", i.e. easy-to-use computer codes, is evident. Even my students want nice computer programs when they work on their exercises. We happen to use a somewhat out-dated slip-circle program for some student exercises and again and again I am told that I should provide them with a better slope-stability program. Users consider the "inside" of a computer code like PLAXIS with different feelings. No doubt, one wants all necessary options for modelling complex engineering works, as everybody understands the complexity of the tunnel or

the excavation he is working on. The complexity of soil behaviour, on the other hand, is not always recognised by PLAXIS users. As a consequence, some of them would rather stick to the simple Mohr-Coulomb model.

3 WHAT IS IT THE PLAXIS COMPANY NEEDS?

3.1 *Memorandum 1989*

As yet PLAXIS is an unfinished computer program. It is advanced in the field of dams and embankments, but it lacks the width for covering the widespread fan of geotechnical structures. The code is reasonably easy-to-use, but it lacks depth when considering the constitutive modelling of soil behaviour. We agreed orally on some such further developments in the year 1989, but as yet there is no contract for the years to come. The future beyond 1989 is completely open, in the sense that nothing has been discussed at all. Until now the development of PLAXIS is thus dominated by short-term planning.

The present short-term planning leads to difficulties within the PLAXIS group. Computer modelling requires both theoretically talented co-workers and staff members which are gifted in the field of information technology. Apart from this we need co-workers with an understanding of geotechnical engineering. No doubt, such engineers are rare and one needs lots of time for recruitment. Once a new co-worker has been recruited, he has to get acquainted to the complexities of the existing PLAXIS program. Therefore his productivity will initially be low and he will consume a lot of working time from the existing team. As a consequence we urgently need long-term planning.

3.2 *Comments 1999*

As in 1989 the development of PLAXIS still requires long-term planning. In most engineering companies this is different, as in contrast to the PLAXIS company they can “hire” experienced staff, which will be immediately productive. Suppose the PLAXIS company would adopt the scenario of becoming a kind of “menu-company”, i.e. a company that makes nice pre and post processing modules for other geotechnical computer codes. No doubt one could make a living by rendering such services to other software companies or to other R & D companies in the field of geomechanics. In such a case one would have to start recruitment of skilled programmers in this field. No doubt the idea of such a “menu-company” that concentrates on the “outside” of geotechnical computer programs will not work as it will be too hard to get and to consolidate enough expertise within the turbulent world of information technology.

Considering the large number of PhD-students in the field of computational geomechanics at various different universities, it would seem more easy to find skilled co-workers for a company that works both on the “inside” and the “outside” of geomechanical finite-element codes. In fact, the feasibility of such a company is demonstrated by the success of PLAXIS BV itself. The long-term stability of this company, however, requires long-term planning and some growth. In 1989 the growth was clear as one had to expand PLAXIS from an embankment-code towards a general geocode. Should we now expand from a 2D towards a 3D-code?

Rather than going for a general 3D-Geo program, I would pledge to develop a 3D-Tunnel code. Most tunnelling problems are really 3D and cannot properly be solved by using 2D-codes. For that reason, there is a large group of companies that would be interested in such software. Together with the present PLAXIS-2D the 3D-Tunnel program will provide a pair of sound “legs” for the company. Such a long-term stable situation is in the interest of all clients who desire continuity. Before reaching this situation the PLAXIS group is challenged to develop a stable and fast 3D-tunnel code. Here the focus is on huge meshes with lots of degrees of freedom. Then non-linear deformation analyses will have to be carried out in a relatively short time; otherwise the tunnelling community will not show an interest.

4 HOW TO PROCEED WITH THE PLAXIS-2D?

4.1 *Memorandum 1989*

Due to the fact that geotechnical engineers have difficulties in handling complex soil models, we implemented the relatively simple Mohr-Coulomb model. In addition to this basic model we will need to implement other more refined models (advanced models) for use by skilled users.

Users can for instance acquire skill on soil behaviour by using advanced models to simulate elementary soil tests. Just like a pilot gets trained in a flight-simulator, geotechnical engineers can sit behind their PC and acquire knowledge on soil behaviour by simple numerical simulations.

On introducing more advanced models, we better not frustrate users by passing in one single step from the simple Mohr-Coulomb model to an advanced model of high complexity. In this context it should also be realised that the quality of computational results does not solely depend on the quality of the soil model being used. Apart from an advanced soil model and a skilled user, one also needs proper soil parameters. As a result of research on in-situ testing as well as lab testing, we may expect increasing possibilities for the procedure of soil-parameter selection.

4.2 *Comments 1999*

Unfortunately advancements in the field of in-situ testing have not been fast in recent years. In 1989 I expected that seismic and pressuremeter testing for the in-situ determination of soil stiffness moduli would rapidly come to use in soil exploration practice. Now it would seem to me that the interpretation of the highly non-linear soil response is so difficult, that it provides stagnation in the fields of in-situ testing. Indeed, interpretations of such tests on the basis of the simple Mohr-Coulomb model have failed and one needs much more advanced constitutive models. The slow advancement of in-situ testing in geotechnical engineering is in my understanding thus a consequence of limited numerical capabilities. The introduction of the Hardening Soil model has improved the situation, as this model matches the non-linear soil response in pressuremeter tests reasonably well. We now need pilot projects where data from pressuremeter tests are used to calibrate the input data for applications of the soil model.

On considering unloading data from pressuremeter tests, one will conclude that the Hardening Soil model cannot match the stiff soil response in small unload-reload cycles. Exactly the same observation will be made when considering data from seismic testing. This proves that further progress is needed in the field of constitutive modelling. At various research institutes this progress has already been made, but as yet it has not been made operational for practical geotechnical engineering. As for the 3D-developments mentioned in section 3, numerical advancements in the field of constitutive modelling have to be robust and easy to use; otherwise they will not be applied at all in geotechnical engineering practise.

On the other hand, when extensions are carefully planned and carried out, it will be appreciated by the geotechnical engineering community, at least by serious geotechnical engineers. From a commercial point of view, one might ask the question whether or not such developments pay off. I am convinced it does, as otherwise PLAXIS will loose contact to geotechnical research and finally it will loose its high-tech reputation.

5 OTHER 3D-SPECIALS

Many users expect and want PLAXIS developments in the field of three-dimensional analysis, as they want advanced options for future projects. The PLAXIS company might respond to such wishes by developing a 3D-code for all possible applications in the field of geomechanics. This would imply tremendous efforts in the field of pre- and postprocessing, as 3D meshes can be extremely complex and special visualisation techniques are needed for input-output operations. In fact, specialist companies on pre- and postprocessing have established themselves to suit the needs of visu-

alising input and output data of 3D codes such as Abaqus, Ansys and Diana. In this way one ends up with software combinations which are both too expensive as well as too complex for use by most companies in the fields of geotechnical engineering.

In order to suit future needs of present users, PLAXIS might go for 3D-specials. Consider for instance the tunnelling code that we already discussed. Here one has a particular mesh configuration (repeated 2D), which is manageable on comparison to most general 3D-meshes. Hence, one can combine preprocessing, calculation and postprocessing in a single software product and sell it to a reasonable price. Such "specials" are not only possible in the field of tunnelling, but for instance also in fields of foundations and excavations. Hence, one might produce computer codes with names such as 3D-Foundation and 3D-Excavation for special geotechnical problems. On considering a particular application one is focussing on particular geometries, which allow the development of manageable and payable 3D-specials.

6 CONCLUDING REMARKS

When considering the future of the PLAXIS code and the PLAXIS company, I have concentrated on the development of new 3D-specials (which might for instance be named 3D-Tunnel, 3D-Foundation, etc.) and further evolution of soil models. 3D-Specials require good knowledge on efficient handling of large systems of equations. At the same time one will have to study the state- of-engineering in the fields of the 3D-specials with great care, as one has to design "tools" that will suit potential users. No doubt, the state-of-engineering will not be the same for countries with different geological conditions and one cannot limit one's thinking to the state-of-engineering in a single country. For further evolution of soil models, one has to bridge the gap between progressive universities and conservative engineering practice. This requires good knowledge of the state-of-art in research as well as engineering.

My focus on the above two items does not mean that these are the only issues for the future. No doubt the new windows version will need some improvements (e.g. the groundwater part) and extensions (e.g. with large-strain consolidation and dynamics). It will be interesting to reread this paper in 2010, as then we will know more about “computational geotechnics beyond 2000”.