What Has the Finite Element Method Done for (or to) Geotechnical Engineering?

The three articles that follow are based on presentations at the ASCE National Convention in Boston in October 1998 by experts on the development and use of finite element methods in geotechnical engineering.

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The finite element method grew out of the aircraft industry, which needed precise computational methods to avoid excessive weight in its products. Before the 1960s most geotechnical engineers — researchers as well as practitioners — had been reluctant to employ numerical methods and computers because the techniques available were not powerful enough to deal with the complicated geometries and nonlinear material properties that occur in practice. Most of the first users of finite element methods were also programmers. Effective use of finite element methods often required that the analyses be done by the programmer. At that time, computers were awkward. They had to be fed with decks of punched cards at inconvenient times and places. Output usually consisted of many sheets of printed paper, which presented another data-processing problem.

As computers became more powerful and more widely available, this view changed. If there is a single point at which the finite element method became a respectable part of geotechnical engineering, it was Clough and Woodward's description of simulating the construction of an earth dam by finite elements and recovering the observed deformations.[1] There followed an explosion of applications. Soon, the technique gained a strong position among the tools available to the geotechnical profession so that today there is a large body of experience in the use of numerical methods for geotechnical problems. Engineers have developed effective ways to deal with many situations and have also learned that some problems remain intractable.

Current Finite Element Capabilities

As computers have become more accessible and easier to use, so too has finite element software. The engineer can obtain a great variety of modern, user-friendly, finite element software suitable for geotechnical applications. First, there are several systems designed specifically for geotechnical engineering. Such packages include PLAXYS, CRISP and SIGMA, as well as FLAC (which is actually a finite difference code). These programs include features unique to geotechnical needs, such as Modified Cam-Clay constitutive models, effective stress analyses, and so on. A second group of widely used programs consists of general-purpose, non-linear finite element systems such as ABAQUS, ANSYS, ADINA and SAP. While these programs were usually written for structural or mechanical applications, they permit the user to incorporate additional routines to deal with peculiarly geotechnical issues. Because of their large capacities and versatility, they are the systems of choice for very large problems with many degrees of freedom or steps of loading. Third, there are the special-purpose programs, such as those that handle dynamic problems or simulation of tied back excavations. Since these systems are intended for specific and limited purposes, their user interfaces are usually less sophisticated than those in the first or second groups. Also, they tend to be more idiosyncratic and buggy.

Considerations

The geotechnical organization contemplating acquiring finite element capabilities can expect that most of the available packages will run well on a modern personal computer. The cost of licenses varies among the different packages, and each system is licensed with a different set of options among the software units. Nevertheless, including the cost of hardware, a satisfactory finite element system can be set up today for approximately $10,000.

However, far larger investment in learning to use the system effectively is required. These systems have learning curves — some are quite steep. Furthermore, if one does not use the system for a period of time, one forgets what has been learned and has to climb back up the learning curve when the next job comes along. Climbing a learning curve the second time can be more tiresome and frustrating than it was the first time. Organizations must be prepared to invest not only in the hardware and software but also in personnel resources to keep skills current.

Finally, as the speakers at the session emphasized, intelligent interpretation of the results is absolutely critical. The most important person in the finite element team is the person who can explain what the results mean. There is a statement, often attributed to John von Neumann, but actually included as the motto of Hamming's classic book on numerical methods: "The purpose of computing is insight, not numbers."[2]

ACKNOWLEDGMENTS & NOTES — *While the session "What Has the Finite Element Method Done for (or to) Geotechnical Engineering?" (held at the ASCE National Convention in Boston in October 1998) was planned as an informal exchange of views, several persons in the audience suggested that, since it provoked a lively discussion, the principal speakers' comments should be collected in* Civil Engineering Practice. *Even though discussion was limited to the finite element method, other numerical techniques — such as finite difference, boundary element and discrete element methods — have found useful application in geotechnical engineering. Many of the insights found in the following three articles also apply to those methods. Professor Stephen G. Wright of the University of Texas, Austin, former chairman of the Geo-Institute Committee on Computer Applications, first suggested the topic for the session, and Brian Brenner encouraged the authors to prepare the written versions of their remarks.*

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REFERENCES

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