NEW AND FUTURE DEVELOPMENTS IN COMMERCIAL FINITE ELEMENT METHODS

Edited by John Robinson

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ROBINSON AND ASSOCIATES Horton Road Woodlands Wimborne Dorset BH21 6NB England

FIRST WORLD CONGRESS ON FINITE ELEMENT METHODS

13-17 October 1975	The Royal Bath Hotel, Bournemouth, Dorset, England
Theme:	State-of-the-Art of Finite Element Methods in Structural Mechanics
Main Invited Lecturer:	Professor J.H. Argyris, University of Stuttgart, West Germany

SECOND WORLD CONGRESS AND EXHIBITION ON FINITE ELEMENT METHODS

23-27 October 1978	The Royal Bath Hotel, Bournemouth, Dorset, England
Theme:	Finite Element Methods in the Commercial Environment
Main Invited Lecturer:	Professor R.H. Gallagher, University of Arizona, USA

THIRD WORLD CONGRESS AND EXHIBITION ON FINITE ELEMENT METHODS

12-16 October 1981	The Beverly Hilton, Beverly Hills, California, USA
Theme:	New and Future Developments in Commercial Finite Element Methods
Main Invited Lecturer:	Professor O.C. Zienkiewicz, University College of Swansea, Wales

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PREFACE

The World Congress on Finite Element Methods evolved after Robinson and Associates learned that there were to be no more matrix methods conferences which had been held at the Wright-Patterson Air Force Base in Dayton, Ohio, USA, in 1965, 1968 and 1971. These conferences were co-sponsored by the American Air Force Institute of Technology, Air University, Air Force Dynamics Laboratory and Air Force Command, and were the most important conferences on finite element methods at that time. Robinson and Associates decided to organize a comparable conference and to hold it in various parts of the world. Hence; the WORLD CONGRESS ON FINITE ELEMENT METHODS. This five-day World Congress is held every three years and was the first major conference in finite element technology to incorporate an exhibition.

The World Congress and Exhibition on Finite Element Methods is a unique forum and market-place for all those involved in any facet of finite element technology. Delegates are able to exchange information on a personal and international level with their counterparts and have face-to-face discussions with leading authorities in the field.

This book contains the forty-two lectures delivered at the Third World Congress. These present new and future developments in FEM technology, covering a wide range of topics and reflecting the international commercial environment and its changing demands.

It is noticeable that new subjects are now being addressed such as education, standards, marketing and legal aspects.

The Third World Congress lecturers were asked to try and project their thoughts into the future and, if possible, be controversial in order to stimulate discussions. I feel they have achieved this goal and would like to thank them for their marvellous response.

John Robinson

Dr. John Robinson, Editor
October 1981

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Copies of Papers 9, 34 and 36 can be requested respectively from:

Dr. H.G. Schaeffer, Schaeffer Analysis Inc., Kendall Hill Road, Mont Vernon, New Hampshire 03057, USA.

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MODERN FINITE ELEMENT PROGRAMS: HOW EASY TO USE ARE THEY REALLY?

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SUMMARY

The Paper examines the ease of use of four well-known finite element programs with reference to a simple geometrically non-linear problem. A user survey on usability of these programs is also presented. The paper illustrates the shortcomings and strengths of the various programs and shows that all of them are difficult to use. It is concluded that to better use the resources of the future, a new approach to finite element analysis is necessary, which requires the minimum amount of effort on the part of the Analyst while maintaining control on cost and accuracy.

INTRODUCTION

It must be well over twenty years since the first "Finite Element" programs were used in the solution of simultaneous equations representing the behaviour of a physical model. One will now find hundreds of finite element programs: NASTRAN, ANSYS, MARC, ASAS, SAP ... the list is endless. Hand in hand with the development of the finite element programs, the computers on which these programs are run have developed beyond comprehension: CRAY, CDC, IBM, VAX, PRIME, Hewlett Packard ... again the list is long.

In recent years the ability of programs to analyse complicated problems and to handle large numbers of simultaneous equations efficiently has improved dramatically, and many of them have become known world-wide and generally accepted as engineering tools. However, the growth of many of the programs over a long period has not always been totally consistent unless a small set of individuals have kept control on the growth over the entire time span. In some cases this has resulted in codes which are often daunting to new users. If one attends courses, seminars or conferences pertaining to these programs, however, one is likely to hear how easy to use, and how 'user friendly' these programs are.

The object of this paper is to examine user reaction to some of the finite element programs available generally, and specifically some of those offered through the United Computing network, and to be able to show how the finite element analysis performs in terms of how it appears to the user. It is also intended to demonstrate that as far as the user is concerned the main area of activity by way of future developments (this being the theme of the conference) should be the user/program interface, which after all is what the user sees, and which he needs to be as simple as possible.

In order to meet this objective two approaches were made. The first one being the selection of a simple problem to see how the various programs, selected for the exercise, got to the solution. The second approach being to obtain the opinions of several users and consultants within a large organisation such as United Computing, in order to obtain an unbiased view of the user impressions of key features of these programs. It should be emphasised that all the programs produced excellent results, and it was not the results of the analysis which were under scrutiny but the process of doing the analysis itself.

PROGRAMS

The programs included in the study were NASTRAN, ANSYS, ASAS and to a limited extent MARC. The choice was mainly governed by the availability of the programs on the United Computing system, and general popularity among users of the system.

USABILITY SURVEY

Table 1 shows averaged results of a survey to determine what users feel about the various programs that they may have used in their finite element lives. The group of people involved in this survey represent mostly a British experience and consisted of analysts and support personnel involved with helping all United Computing clients in the U.K. to use finite element packages as part of their role. Hençe the survey represents to a large extent opinions of a very large group of clients spread over innumerable industries. The good and bad points of each program outlined in the various sections that follow, partly reflect the response to this survey. The delegates at the conference may compare this estimate to their own views though it should be borne in mind that the World Congress delegates are generally more committed to the finite element method than a new or recent recruit would be, and experience is likely to colour judgement to a degree.

THE PROBLEM

The problem that was used to illustrate the use of the various programs consisted of a clamped square plate under uniformly distributed loading (Ref.1). The pressure imposed was intended to produce deflections in the plate up to twice the thickness of the plate, hence introducing geometric nonlinearities in the analysis. The ability to perform this type of analysis also limited the choice of programs to some extent.

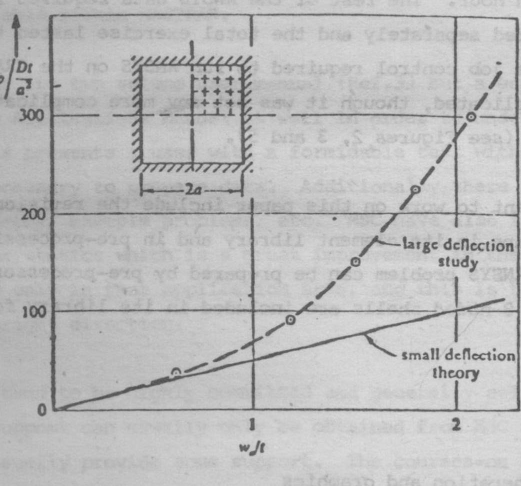

Figure 1. Central deflection, w_c, of a clamped square plate under uniformly distributed total load p.

ANSYS

This universally used program is a product of Swanson Analysis Systems in the United States. The program has a wide analysis capability including linear and non-linear statics, dynamics, heat transfer and eigenvalue buckling. The program also has comprehensive pre- and post-processing capability which may be used on its own or as part of the ANSYS analysis.

The two volume ANSYS user manual (Ref.2) is a good reference manual though it is not very readable. There are also several auxiliary manuals for theory, verification and fully solved examples. Further information and support for the program can be obtained from most bureaux and directly from SASI.

SASI run excellent, regular 2-5 day courses which are reasonably priced, though the attendee gets no real experience in using the program, which is unfortunate, but understandable considering the wide range of computers on which it may be used.

The ANSYS data for the test problem was prepared using the pre-processor PREP7. It was found easy to learn and to use and the simple mesh of the example took less than an hour. The rest of the ANSYS data required for the analysis had to be prepared separately and the total exercise lasted two hours (see Table 2). The job control required to run ANSYS on the CRAY1 can only be described as complicated, though it was not any more complicated than for NASTRAN or MARC (see Figures 2, 3 and 5).

New developments subsequent to work on this paper include the revision 4 of ANSYS which has closed gaps in its element library and in pre-processing. The entire data for the ANSYS problem can be prepared by pre-processors and the new plastic beam and 8-noded shells are included in its library for the first time.

Strong Points

1) Interactive model generation and graphics
2) Easily driven pre- and post-processors
3) Flexibility of interactive and batch processing
4) Cheapest of the programs used with analysis on the CRAY-1.

Weak Points

1) Element library large, though a bit basic for any particular class of problems, e.g.: eight noded shells were not available until revision 4, though the results from more four noded shells were found to produce sufficiently accurate results.
2) Element stress printout makes it necessary to use a post-processor to select specific stresses to be printed out in neat tables.
3) System job control for CRAY a bit messy, though macro programs developed at United Computing help this considerably.

NASTRAN

This program is also well known and its most widely used version on the UCS service is MSC/NASTRAN, marketed by MacNeal Schwendler Corporation. NASTRAN also has a very wide problem solving capability including special solution schemes for symmetry and superelement analysis. In addition user solution schemes may be defined using the DMAP language which is a programming language available within NASTRAN.

NASTRAN too has its two volume user manual (Ref.3) but a user needs to have the two volume Applications Manual as well in order to understand the data required. This presents a user with a formidable task with a lot of cross referencing necessary to prepare data. Additionally there are separate manuals for theory, example problems, etc. MSC have also introduced a handbook for linear statics which is a great improvement in the documentation for users involved only in that application area, and this is to be welcomed as a step in the right direction.

NASTRAN users tend to be highly committed and generally self-supporting, and good NASTRAN support can usually only be obtained from MSC themselves though bureaux will usually provide some support. The courses on NASTRAN are run by MSC and Schaeffer Analysis, but are less frequent than for ANSYS.

The data for elements and coordinates of grid points for the test problem were prepared using the SUPERTAB graphics program, which provides a NASTRAN interface. The use of an independent program like SUPERTAB is an indication of the fact that data preparation for NASTRAN direct was considered totally unsatisfactory for the modern user; such NASTRAN pre-processing as exists is restrictive in that it can only be used in batch mode as an integral part of NASTRAN. The rest of the NASTRAN data required extensive searching through the user and application manuals. It was felt that in a way NASTRAN suffers from too much flexibility as it is not possible to document it in a logical way. A good example is the way the Bulk Data cards are alphabetically documented in the user manual without an index, which means that the user has no idea what facilities are available in doing a NASTRAN analysis. For the test problem it took four times longer to prepare the NASTRAN data compared to the ANSYS data preparation.

The job control required for running NASTRAN on the CRAY varies from small to considerable depending upon whether the analysis required restarts or rigid format alters. In the case of the test problem the job control was simple (see Figure 3). If the entire non-linear curve of Figure 1 was required then the NASTRAN analysis would require restarts with the associated complications.

Post-processing in NASTRAN takes the form of either plotting from within NASTRAN, or use of MSGSTRESS external to NASTRAN. The latter is restricted to models generated using the MSGVIEW model generating routine within NASTRAN.

Recent developments for NASTRAN have been the introduction of version 61 which updates several solution sequences and introduces material non-linearity solution for the first time. The processor called GRASP is also expected to provide a friendlier interface for the user, but it has not been possible to evaluate this at the time of writing.

<u>Strong Points</u>

1) Very strong on special solution sequences for symmetry, aeroelasticity, dynamics and superelements.
2) Very flexible and usually several alternatives to achieve the same objective.
3) Optionally 'programmable' through DMAP to produce uncommon effects, though this is difficult and also reduces portability of the data between machines

4) No limitation on problem size.

Note that none of the above really contribute to ease of use.

Weak Points

1) Documentation not well designed and voluminous.
2) No practical pre-processing available to help the user to prepare a formidable amount of data. Using other pre-processors means learning how to use other programs.
3) Not well suited to non-linear problems. The geometric non-linearity solution is not very elegant and requires several restarts in general. Material non-linearity not present until recently.
4) Too much flexibility and various capabilities not adequately dealt with in the documentation.
5) No interactive post-processing.
6) Reliance on operating system processors to set up specific conditions to run DMAP sequences.

ASAS

This is a program better known in the United Kingdom and is marketed by Atkins Research and Development. The standard version of the program has analysis capability only for linear statics and real eigenvalue analysis. Although fundamentally a linear-only package, ASAS has been included here because a solution sequence based on the data bases of the ASAS program has been developed to handle the geometrically non-linear problems (Ref.5) and it was this algorithm which was used to solve the problem. Because this is not part of the standard package as marketed by the owners, the author has restricted his comments to the use of the ASAS program itself.

The user manual for ASAS (Ref.4) is regarded in the United Kingdom as one of the best and is certainly very clearly laid out. However, the auxiliary documentation is non-existent. There are no manuals, such as is customary to expect these days, on theory, application or verification. Support for the program comes from the various bureaux and from the owners themselves. No regular training courses are offered by the owners, but there are regular two-day courses on the use of the program held by United Computing. Because of the need only to cover linear analysis a reasonably full grounding in the program can be given, with substantial practical sessions; the author's experience is that the value of this to the new user is immense, and can go a long way towards overcoming 'manual-blindness' in the case, for example, of ANSYS or NASTRAN.

There is no model generation type pre-processor for ASAS, though the ASAS data has good internal data generation capability, and the total data can be very concise indeed, and certainly much briefer than with any of the other programs. Thus a user has to prepare the entire ASAS data prior to the use of the program. This can be a more expensive exercise, in terms of the time required, than the ANSYS type data preparation with help from a model generator, and the time required to set up ASAS data for the test was twice that required for the ANSYS model (see Table 2).

The job control required to run ASAS on the SIGMA 9 computer is the smallest of any program used in this study and in this case the non-linear algorithm prepared all the necessary job control internally.

Post-processing on ASAS is available for all the elements in the library but is external to ASAS. This usually requires a user to run two or three programs to obtain the desired results and to keep track of all the associated disc files. Although the logic involved is straighforward, it can be confusing to the unfamiliar user, and puts unnecessary administrative considerations on the regular user.

The ASAS program is likely in the future to have increased analysis capability with the addition of non-linear analysis and a range of dynamic analyses. The version H of the program recently introduced has a multi-level substructuring capability and more elements in its already impressive library.

Strong Points

1) User manual very good
2) Job control minimal
3) Very sophisticated elements and a good element library

4) Solution sequences offer both 'in core' frontal solution and 'out of core' banded matrix solution.
5) High quality of presentation for post-processing - tabular and graphics.

Weak Points

1) Analysis capability limited
2) No pre-processors to generate data though graphical display of assembled model is possible.
3) Program more expensive to run compared with the others (though results from comparing the first three programs all on the CRAY-1S not yet available.)
4) Post-processing requires running two or three programs external to ASAS.

MARC

This program is marketed by MARC Analysis Research Corporation and is known for its non-linear analysis capability, though less so in the United Kingdom. Unlike NASTRAN where flexibility is introduced by modification of DMAP sequences, in MARC user FORTRAN programming is available to affect results or generate data. However, this does require further commitment from a user, and cannot be rated an ease-of-use feature.

The user manual (Ref.6) performs several functions and is generally considered not to be detailed enough. Areas of applications are dealt with too briefly, probably because of the spectrum of subjects dwelt upon. In Britain training courses and technical support for the use of MARC are not available and the program is not very easy to drive for the new user.

The data for the test problem was assembled with the help of FORTRAN routines. The MESH3D processor in MARC, which works on an integer space basis was not utilised in this case for the sake of uniformity of comparison, and it was not felt to be a suitable tool for the average user with realistic structural problems.

The job control required to process the data was considerable because of the presence of FORTRAN routines. (See Figure 5). The time required to assemble data was comparable to NASTRAN and four times as long as ANSYS (see Table 2).

Post-processing in MARC is available both internal to the program in the form of graphical output and by using the MARCPLOT program external to MARC.

Strong Points

1) Caters for many kinds of geometrically and materially non-linear problems.
2) Very flexible if user is familiar with FORTRAN programming and experienced in MARC.
3) Some data generation capability with user-defined routines or MESH3D.

Weak Points

1) To get maximum program benefit the user needs training in FORTRAN though the manual gives simple examples.
2) Manuals not very easy to follow though better than NASTRAN.
3) No interactive data preparation.
4) Not well supported everywhere.
5) User training not available as often as would be useful.

CONCLUSIONS AND RECOMMENDATIONS

Looking at the evidence presented, it appears that the finite element analysis capability is now very far in advance of the 'average' user's needs, but in terms of the friendliness to the user, most programs leave a lot to be desired. Most programs still appear to be adopting an attitude of superiority to the user industry on which their existence to a large extent depends. The current situation is ripe for consultancy-type organisations who specialise in specific programs and provide an analysis service to the industry. However, the author would suggest that the Finite Element method will not become a household word unless the programs appear a lot more accessible and usable to the people involved in day-to-day design requiring Finite Element applications. It can be seen from the comparisons that there are programs which have invested more effort in making life easier for the user and it is quite obvious