

A Modern Approach of Large Computer Codes for Structural Analysis

Pierre Verpeaux, Alain Millard, Thierry Charras, Alain Combescure
CEA-CEN, Gif sur Yvette, France

INTRODUCTION

In the past, the development of computer codes for structural analysis has led to large systems, which are often difficult to use and to maintain. There is a necessity for new codes, which may be used in different ways according to the various needs and requirements :

- development of new possibilities in order to treat new problems.
- facilities for advanced users, which are familiar with the numerical methods associated with their physical problem and who want either to modify standard methods used in the code or even test new methods.
- use of the code as a black box, for the treatment of "classical" problems by basic users.
- interactive possibilities which can help the user by guiding his answers.

SOME CONSIDERATIONS ON PAST COMPUTER CODES

The computer codes which have been developed in the seventies have been influenced by the computers, and their architecture is strongly dependant upon them : previously, computers had small memory capacities, they were not so reliable as today, and were operated in a batch mode. Consequently, one of the main concerns when writing a computer code, was to save memory, which resulted in a complicated implementation of arrays.

Some possibilities of stop and restart had been introduced after all the important steps of the analysis, and the users spent much time to prepare and check their data. Finally, the computer codes were written to treat specific problems, and the multiplicity of problems has led to a large number of codes, usually unable to communicate if necessary.

The first improvements brought to these codes were on one hand the dynamic memory allocation, in order to treat problems as large as authorized by the computer size, and on the other hand the data input without format.

Nevertheless most of the data remained numeric (for example nodes and elements numbering) and therefore difficult to read and check.

The codes which were originally written for some specific applications were extended to treat new problems and then became more and more complex and difficult either to develop or to maintain. In parallel, computers memory and power increased and offered new facilities like graphics and interactive mode.

With other respects, the size of the computer codes rendered it necessary to share the development between different people, on different places.

All these considerations have motivated a new generation computer code called CASTEM 2000.

ANALYSIS OF A CALCULATION

A complex calculation using discretisation techniques like finite elements, can be decomposed into several steps :

- 1 - definition of a discretized representation of the domain, i.e. meshing.
- 2 - definition of a certain number of properties on this mesh. These are the coefficients which appear in the partial differential equations and boundary conditions of the problem.
- 3 - solution of the discretised system.
- 4 - analysis of the results.

From an user's point of view, it is necessary to dispose of tools to visualize and control the input data, to store and retrieve some informations and to rerun the above mentioned step.

These steps can themselves be seen as a sequence of elementary operations having the following basic working process :

- to get some existing information,
- to process it,
- to generate some new information.

Finally, making a calculation consists in selecting the relevant elementary operations and in supplying them with the required information. It can be noticed that among all these operations, only a few are specific of the problem to solve.

PRINCIPLES FOR THE DEVELOPMENT OF CASTEM 2000

In order to be able to do various types of calculations, CASTEM 2000 comprises all the elementary operations which have been used in the old codes, and can welcome the new ones, required to treat new problems. The operations are called OPERATORS and the pieces of information are called OBJECTS.

The development of CASTEM 2000 is based on the strict observance of five principles :

- orthogonality of operators, i.e. : the operators are independant, and they can be combined. For example, the operator which solves linear algebraic systems is independant of the one which makes the elementary stiffness matrices.
- visibility and locality of the operators, i.e. all the data must be explicitly supplied to the operators and there where they are used. As a consequence, the information generated by an operator must also be visible.
- regularity of the operators, i.e. on one hand there are no exceptions in the use of an operator, if the operation is possible, and on the other hand, there are no exceptions in the data syntax. For example, in CASTEM 2000, a plan is always defined by three points.
- documentation of the operators : it is a part of the operator and it must be developed simultaneously.

IMPLEMENTATION IN CASTEM 2000.

The objects used in CASTEM 2000 are referenced by their name, given by the user. The operators have a name which is recognized by the code. The elementary operation in CASTEM 2000 can then be written as :

result = operator object ;

and a calculation is a sequence of such basic instructions. The only working condition is that the information "object" exists when the operator will use it.

For example, suppose that a closed line is referenced by its name LINE. The surface contained inside the line can be generated by :

SU1 = SURFACE PLANE LINE ;

where SURFACE is the name of the operator

PLANE is a key word to identify an option of the SURFACE operator

SU1 is the name of the generated object.

Since a calculation involves various kinds of information like meshes, floating numbers, nodal fields, element fields, matrices, etc..., the objects have been typed, and a specific informatic structure has been adapted to each type. This enables a syntactic test of the data, at the operator level.

THE POSSIBILITIES OF CASTEM 2000

As already mentioned, the operators required for the treatment of classical problems in the fields of structural and thermal analysis have been implemented in CASTEM 2000. There is no distinction between pre-processing, computation and post-processing operators, like in the old codes.

Treatment of new problems

The treatment of new problems may require either new operators, or new object types or both. It is very easy to introduce a new operator thanks to the above principles : development and tests can be made independantly of the existing operators. The addition of a new object type is very seldom and more difficult because of the regularity principle.

Language facilities

Since it is often necessary to repeat some operations and to test some values, the corresponding operators have be implemented as well as the major algebraic operations. Thus, the user has the possibility to program his own algorithms to solve his problem. He does not use any more a black box but a tool that he can himself modify.

Procedures

In some problems, a group of elementary operations may be used several times and it is desirable to replace them by a single instruction. In other respects, for non trivial problems like plasticity or large displacements, it is not reasonable to let the user define explicitly the solution algorithm. Therefore it is more convenient to come back to a black-box working mode.

Finally, the user might want to supersede an operator by another one or even to create himself some new operators without going into programming difficulties.

All this became possible thanks to the procedures, which are meta-operators, i.e. operators written in user's language and which have the following properties :

- then can be used as operators,
- then can use other procedures or operators,
- they can overlay any existing operator or procedure,
- they are totally visible.

It is even possible to use them in an interactive way thanks to two specialized operators :

- MESSAGE, to ask questions to the user,
- OBTENIR, to get answers from the user.

CONCLUSION

The experience gained during some 15 years in the development and use of large structural analysis computer codes has led to a modern code, CASTEM 2000, based on the concepts of operators and objects, and some principles of development. It is a very general and powerful tool, which can be adapted either to basic users or to highly specialized engineers.

REFERENCES

- [1] Verpeaux P., Millard A., "De l'existence à l'essence ... de CASTEM à CASTEM 2000" - Report CEA/DEMT 88/179
- [2] Charras Th. et al, "CASTEM 2000 - A new generation of general purpose finite element code" Report CEA/DEMT 86/312
- [3] Ebersolt L. et al, "Non linear algorithms solved with the help of the Gibiane macro-language" - Paper B 3/2 - SMiRT 9 - Lausanne, 1987.
- [4] Verpeaux P. et al, "CASTEM 2000 : A modern approach of computerized structural analysis" - Proc. of "Recent Advances in Design Procedures for High Temperature Plant" - Risley, 1988.