

# DEVELOPMENT A MATRICIAL NUMBER METHODS PROCESSOR IN A VIRTUAL LABORATORY TO STUDY OF LINEAR CALCULATIONS OF STRUCTURES

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**Keywords:** Structures, Linear Calculation, Elasticity, Matrix Structural Analysis, Simulation.

**Abstract:** In this work is presented an introduction to the main design features of a computer-aided educational package addressed to students of the final years of Mechanical Industrial Engineering. The software includes interrelated tutorial, computer simulations and test questions in which graphical outputs, hypertexts and animations are widely used. The package is devoted to the simulation study of the Calculation of Structures. The application includes the representation of virtual environments in 3D and lineal calculation methods which result a virtual laboratory which aim is the representation and calculation of stresses and deformations in structures, as well as giving the user access to information on the degree of training reached. The software has all the following features: an integrative character, self-evaluation tests, and a personalized and active learning process, adaptability to teacher's aims, versatility as a teaching tool, multimedia resources, and simplicity. This study has been completed with final-year students at the Superior Polytechnic School of Cordoba (Spain), with highly favourable results when compared with students who did not use the software.

## 1 INTRODUCTION

The future presents itself as a continuous learning process in a rapidly changing world.

Simulation is the practice of generating models to represent a system in the real world or in hypothetical future worlds. The reasons why simulation has been widely employed are, among others, the degree of realism that can be included in the simulation models and the ease with which these models can be explained.

Computers can be used as a complementary tool in the learning by discovery process (Clive L.Dym, 2004). By using the computer as a simulator of phenomena, the student can discover models that initially remained concealed (Murphey TD, 2008, Balamuralithara, B. C. 2009).

The creative process of designing the structure of a building involves imagining the characteristics of the materials to be used, the dimensions of the

resistant elements which make up that structure and the structural typology suitable for the building problem to be solved (Anderheggen, E. Et al. 2005).

In teaching, the software used are, first closed programmes as ANSYS, ROBOT, etc., other calculation programmes with a general purpose generally written in FORTRAN language, included in specialized texts which permit the user to adapt and manipulate them but which do not include interactive environments (Livesley, 1970) and finally, educational software in which text files created by it can be directly imported to the FEM software ANSYS so as to analyze stress distribution of the shaft (Álvarez-Caldas, C. Et al. 2006) .

With the aim of facilitating the learning of the student of Structure Calculation we have created a multimedia virtual laboratory (VisualBasic vs. 6.0, C++ and Flash) to permit the making of calculations and the visualization of graphic results, as well as animations and photographs. The advantage of our system with similar ones ( Álvarez-Caldas, C. Et al.

Miguel Martínez Jiménez J., Martínez Jiménez P., Miguel Martínez Valle J. and Martínez Valle A. (2010).

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In *Proceedings of the 2nd International Conference on Computer Supported Education*, pages 427-430

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2006), is that we have developed and integrated a processor, MOSOBA, which aims either to provide the expert with the storage of data derived from the creative process, or to didactically guide the non experienced person in the anticipation of forms and materials.

## 2 VIRTUAL LABORATORY DESCRIPTION

In the computer application developed, a series of sections has been included among which tutorials and simulations of problems posed stand out.

When initiating the laboratory the first decision the student must adopt is that of evaluating his/her level of knowledge on the theme being studied. For this, the program computer offers the possibility of reviewing previous concepts which the student should have acquired in previous courses in the Area of Mechanics of continuous media and Resistance of materials, and/or to study the tutorial expressly related to the simulation in course (Zienkiewicz, 1980; Zienkiewicz et al., 1994).



Figure 1: Real building cases.

The activity carried out consists of presenting to the student, through photographs incorporated into the laboratory, a real building case already constructed, for example an industrial hangar, a sports stadium, etc. (Figure 1). Once the prescribed discretization has been studied, the main characteristics of the structural typologies to which the building in question belongs can be found in the tutorial, as well as the possible modifications which can be conceived in supports, joints, load states etc.

The calculation (linear) module called Mosoba, developed by our researchers group, is the one which permits the carrying out of the actual simulation and supplies lists and graphics of stresses and deformed lines of the different situations which have been conceived. Mosoba is a processor which aims either to provide the expert with the storage of

data derived from the creative process, or to didactically guide the non experienced person in the anticipation of forms and materials.

Mosoba has been developed in a Windows environment, directed towards the resolution of different typologies of bar structures: articulated and rigid, flat and spatial, and grid, nodes, in which three well defined stages can be differentiated: pre-process, calculation and post process, it is being in the second and third stages when the verification and simulation necessarily prior to the construction are produced.

Finally, an Evaluation module has been included which permits the teacher to monitor the student's learning process in relation to the characteristics and suitability of the structural typology adopted, as well as on the degree of optimization achieved according to the solution selected.

## 3 DESCRIPTION OF THE MOSOBA MATHEMATICAL PROCESSOR

The processor Mosoba is only wished to be a faithful reflection of a methodical and methodological application in relation to the matrix calculation of structures and bars and with the calculation programming coherent with that theory. Thus it has no other aim than to set up a database which can be visualized by means of the option "see Data file" (file in text) in Edition of the Tools bar, which contains in an orderly form: the name of the structure and typology to which it belongs, abscissa, ordinates and heights (if necessary) of the structure nodes, types of different bars making up the structure, definition of all the bars, loads on nodes, and, if appropriate, on the bars themselves, as well as the identification of the coerced nodes.

As has been stated, Mosoba arose with a didactic vocation but that does not prevent it from being a fast, powerful pre-processor, capable of easily resolving complex and real cases, and, of course, most of those which can appear in professional practice. At this moment we are not referring to the capacity of resolution of problems with a large number of unknowns, but, on the other hand, to the agile, attractive and graphical preparation of the data which should be included in the file "Data" and which we shall represent, in a Windows screen, as we go on inserting them.

Although we shall now mostly refer to the cases of flat structures, which are the most frequent, it

should not be lost from view that the same ideas have been transferred to spatial ones. Once the structural type to be considered has been selected, the first data to be inserted will be those relative to the position of the nodes in a specific reference system, an operation which can be executed both by supplying the coordinates of the nodes and clicking the mouse at the point indicated.

Although this insertion of the nodes is interactive, handy and sufficient for a large amount of cases, for example the reticular structures of rigid nodes, there are other cases, like the planar parabolic truss with articulated nodes in Figure 2, in which, for having a large number of nodes and not fitting the vertices of a reticule, the insertion of the nodes by coordinates would be troublesome. For these cases the facility for automatically generating a set of nodes regularly spaced over one curve has been conceived. The possible curves are either flat conical ones or a generic one defined by a polynomial of up to a fourth order. In the spatial cases similar criteria are followed (Figure 3).

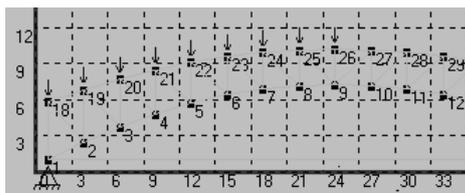


Figure 2: Planar parabolic truss.



Figure 3: Flat bars with rigid nodes.

To control the correct insertion of data we have provided the options: List the nodes, erase all the nodes or erase only the nodes that we select previously, permitting us to ensure their definition, or, if necessary, to correct the mistaken one. Next, we shall define the bars, first the geometric and mechanical characteristics of one or several bars whose initial and final nodes will be indicated next. The latter can be indicated in the corresponding dialogue square or by clicking the mouse on the initial and final node of each bar, with the possibility of choosing, or not, to visualize the corresponding numbering.

In the same way as in the case of the definition of the nodes, we have set up the facility to generate

elements systematically, starting from a previously defined element. Repeating this operation a few times can provide us with the definition of all the bars, which may be a great deal, of structures like that of the example, in which once the bar 1-2 of the bottom bar has been defined, the facility that we mentioned allows us to generate the 15 following ones on the mentioned bars (2-3 to 16-17).

For the definition of loads and coersions we have the same options as those mentioned for nodes and elements, i.e. we can define them individually in specific nodes, generate them automatically in several nodes with a single order, we can list them and erase them, etc.

For the case of flat structures with rigid and grid nodes, there is a possibility of inserting distributed and occasional loads, in any number, on the bars (Figure 4).

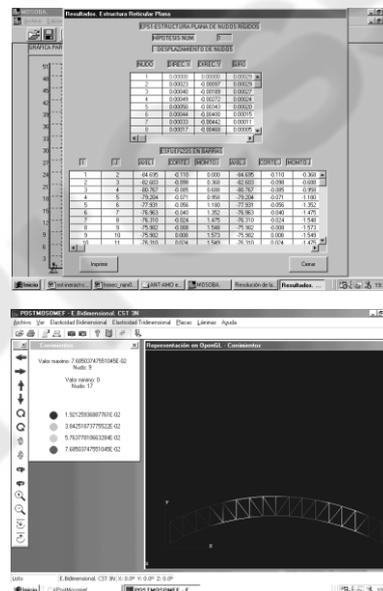


Figure 4: Numerical and graphical result of the study.

## 4 DIDACTIC EVALUATION OF SOFTWARE

This virtual laboratory has been used, from a didactic point of view, as a computer-simulated laboratory experiment, with 3<sup>rd</sup> year technical engineering students and for five years running.

In order to assess the educational value of the program, a comparative analysis was made of the learning results achieved by students who had worked with this tool (experimental groups GE1 and GE2) and other students at the same level who

followed a traditional teaching method (control groups GC1 and GC2) based on a theoretical exposition and problem resolution. The two experimental group students did the problem resolution classes and worked in small groups for various sessions with the simulation program, following the instructions in an activity program guide, which included different kinds of activities.

The evaluation of the learning program was made through an analysis of the individual reports of each student and a complementary questionnaire. The same evaluation process was followed with the control group students. The two experimental groups (GE1=65, GE2=70) and the two control groups (GC1=72, GC2=67) were similar in their average age, level of studies (3<sup>rd</sup> year of Engineering) and previous knowledge.

The analysis of the evaluation data was made from a classification of the results obtained by the students organized in four different learning categories: I (deficient), II (acceptable), III (good) and IV (very good). On analyzing the first results it was observed that the individuals in the experiment groups generally achieved better results than those of the control groups.

From these results, some facts worthy of mention can be deduced: 1) the evaluation process gave similar results in the two control groups GC1 and GC2, so that the system used can be considered as being reliable. 2) Similar results were observed in the experiment groups GE1 and GE2, using the same evaluation method, so that we can consider the learning process to be homogeneous. 3) Statistically significant differences were noted between the degrees of progress of the experiment groups with respect to the control groups. The greatest differences were seen in level I (deficient) this being much greater in the control groups, and in level III (good), notably higher in the experiment groups.

From these facts, it is deduced that the instruction process followed in the experiment groups enabled students to achieve a higher progress level than in the control groups and that the program used constitutes a useful instrument for improving the learning process.

## 5 CONCLUSIONS

A computer application which objective is the identification and numerical and graphical study of Structures has been developed. A similar structure to other specific Calculation software has been followed: CYPE, TRICALT, etc. or to that of

analysis by the Finite Element Method, ANSYS, ROBOT, etc. (pre-process, resolution and post process).

The MOSOBA processor is intended to be programme for training prior to the use of more specific software. It has been created in a WINDOWS environment to make it more attractive to the novice and permits the resolution of a structure very easily and in a short interval of time. That is to say, it is wished to keep its didactic nature although it is provided with enough power to tackle, in combination with specific programmes on reinforced or prestressed concrete or metal structures, complex problems with the added advantage of being able to control, in a highly personal way, the value of the parameters taken into account in the structure's design.

This study has been completed with final-year students at the Superior Polytechnic School of Cordoba (Spain), with highly favourable results when compared with students who did not use the software.

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