



STRUCTURAL MECHANICS: A DIDACTIC EXPERIMENTAL SET-UP AND ITS VIRTUAL TOOL

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6th Int. Conference on

*Emerging e-learning
Technologies
and Applications*

*The High Tatras,
Slovakia
September 11-13, 2008*

Abstract. A didactic test frame was developed for use in Structural Mechanics classes. It enables the evaluation of support reactions in isostatic and simple hyperstatic structures, as well as the measurement of flexural displacements and the determination of influence lines in beams.

Hands-on activity is fundamental in engineering education but large classes call for the replication of experimental set-ups which may become costly in some cases. Efficient complementary solutions may be provided by recourse to information and communication technologies. In the present case two alternative approaches have been explored. In the first one the real experimental set-up was used as a remote laboratory tool for demonstration during lecture classes. An IP camera captured the laboratory images that were projected live on a large video screen for up to 100 students. The second approach involved the development of a software tool specifically designed to complement the existing didactic test frame prototype. This paper describes both, the experimental set-up and its virtual tool.

Keywords: Engineering education, Hands-on activity, Virtual laboratory, Remote laboratory, Learning object.

1. INTRODUCTION

A major problem when teaching a course to a large student audience is the difficulty to engage the whole group during the whole lecture. Nowadays this is a universal predicament, not only due to the continuing expansion of student numbers but also due to their diversity of psychological and learning profiles [1, 2]. And of course things get even worse if the temptation becomes too strong to use wireless Internet access or to manipulate the cell phone during the class. An efficient strategy has yet to be found to solve this difficult problem.

How can instruction be personalized and more interactive yet with large student numbers? Many of us are trying to find solutions [3, 4]. Learning from the experience of other people will help and it is also important to realise that this is not a personal difficulty, but a widespread dilemma.

The contribution described here shows how to improve the presentation of conceptual issues while getting at the same time student involvement and good management of large courses. The main tools are based in the use of experimental demonstrations and technology.

This work reports on the use of a didactic test frame dedicated to the teaching/learning of Strength of Materials and Structural Analysis courses for Mechanical and Civil Engineering students. The experimental set-up, of moderate cost but of considerable dimension, can be accessed remotely during lecture classes, for demonstrating important features related to structural concepts, by using a pan and tilt control network camera with digital zoom for close up

images, together with Skype® software for voice communication and an Intranet connection. With this architecture the students are able to explore, communicate, analyze and share information and ideas in real time with a trained student that is in charge of manipulating the test frame in a laboratory elsewhere in campus.

Questions can be addressed to the student operating the experimental setup and an interactive and constructive dialogue can take place. The teacher should mediate the process and conduct the presentation.

Considering that simulations are typically structured presentations that are designed to involve students in a specific situation, a virtual tool was also designed and developed for complementing this experimental support. It was designed to mirror real issues that students may encounter in this topic of study. Students from the Informatics Engineering Department were involved in its development. This virtual tool is available for download to any student.

These two complementary tools, the real and the virtual one, if well explored, have the potential to cater for all individual learning styles, appealing in various different ways to the sensing, the intuitive, the visual, the verbal, the active, the reflective, the sequential and the global learners [2].

Section 2 briefly describes the experimental set-up. On section 3 the virtual tool is presented and on section 4 a final comment closes the work.

2. THE EXPERIMENTAL SET-UP

This equipment has been designed as a didactic tool for performing structural mechanics experiments within the context of courses of Mechanics, Strength of Materials and Structures, for both Civil and Mechanical Engineering students, Fig. 1.



Fig. 1. Didactic test frame for structural mechanics

The versatility of the equipment permits a variety of tests that can be readily performed, such as:

- Determination of support reactions in isostatic structures, Figs. 2a and 2b;



Fig. 2a. Test of a simply supported beam



Fig. 2b. Determination of reaction force

- The measurement of structural displacements, Fig.3;

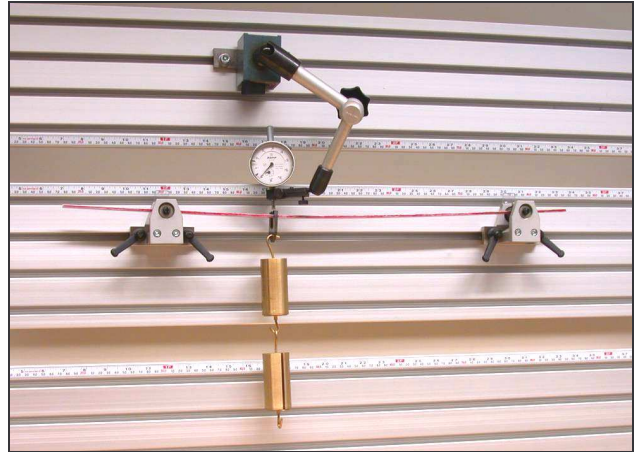


Fig. 3. Measurement of the flexural displacement in a simply supported beam

- The study of simple hyperstatic structures and the determination of influence lines in continuous beams, Figs. 4a and 4b.



Fig. 4a. Influence line for shearing force



Fig. 4b. Influence line for bending moment at a section of a two-span continuous beam

The set-up permits a direct contact with the principal concepts and methods of structural analysis, whereby the introduction of the theoretical background can be combined with the visualization of the physical phenomena [5].

The use of Skype® software and an IP camera for simple sound and image communication using Intranet are all that is required to bring into the large lecture theatre the live demonstration of the structural behaviour.

The system has been conceived, designed and produced at the Faculty of Engineering, University of Porto (FEUP).

The test beam set has several aluminium and steel bars. The support mechanisms (fixed supports, hinged supports, roller supports), the set of loads, non-sliding hangers and other components can be stored in an aluminium case, Fig. 5.

The whole system, considering the estimated cost of production plus the IP camera, represents a modest total investment not exceeding 3.000 €. But many of them would

be required in order to provide 500+ students with sufficient opportunities for individual hands-on practice. The idea of creating a virtual workbench, reproducing the real one and using free software, has therefore been identified as an essential and important complement to the experimental structural mechanics set-up. And, it was the next, logical step of this process.



Fig. 5. Test frame accessories in the carrying case

3. THE VIRTUAL TOOL

SoftBeam is the name of the virtual reality application whose development has been an interdepartmental venture between Electrical, Civil and Mechanical Engineering Departments.

A small grant was awarded by the University of Porto within the framework of an initiative that supports and stimulates the involvement of undergraduate students in R&D activities.

The primary objective of SoftBeam, a freely available application, is to provide students with easy access to the main features of the didactic test frame in order to facilitate knowledge integration with the perception of demonstrations (“seeing is believing”), to promote “virtual practice” and its feedback, to look for meanings, to replicate the experiments, to observe details, to stimulate cooperative activity, to feel how it works, to learn sequentially, to synthesize knowledge [2].

The SoftBeam simulator reproduces the test frame with a high degree of realism, offering three distinct default camera views. The panoramic view, Fig. 6, welcomes the user to a friendly virtual environment where the test frame is the central object [6].

Like in the real set-up different experiments can be selected and handled using the three available views, allowing the

user to reproduce within his PC, anytime, anywhere, tests similar to the ones performed in the real test frame.

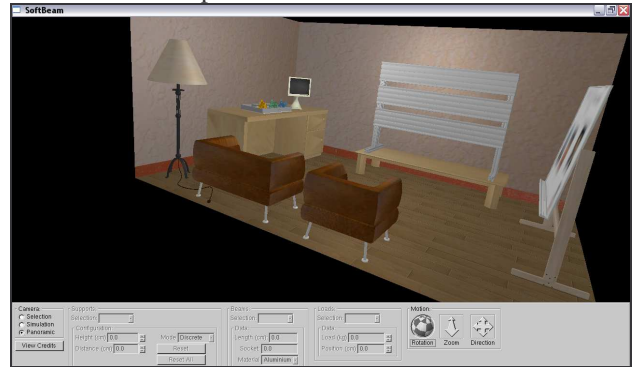


Fig. 6. SoftBeam panoramic view

The selection view, Fig. 7, allows the user to visualize and select the available support types and to choose from a set of masses to define the applied loads. Each time a mechanical component is selected the monitor displays its technical denomination.



Fig. 7. SoftBeam selection of support types

Once an object is selected by the user in this view the simulation view is activated to define the object location on the test frame, Fig. 8.



Fig. 8. SoftBeam simulation view

When the object layout is completed the user triggers the structural analysis module, based on the displacement method, for handling the structural problem, whose solution is then available in the results output section. This view can display diagrams of shear and axial forces, as well

as bending moments. It also enables the user to obtain the numerical value of displacement and rotation at any section of the structure and reaction force components at the supports.

The SoftBeam application has been developed in OpenGL computer graphics software, [7], with a structural analysis module coded in Fortran.

4. FINAL COMMENTS

The didactic test frame has been used for demonstration at lecture classes on a module on Influence Lines taught to 3rd year Civil Engineering students during the 1st semester of 2007/2008.

At the end of the module four questions were posed to the students:

- Question 1: How much did the test equipment contributed to a better appreciation of the underlying theory?
- Question 2: To what extent did it provide a deeper understanding of the influence line concept?
- Question 3: Did it improve the ability to solve influence line problems?
- Question 4: Would you like to have a virtual replica of the experimental setup on your laptop?

The questionnaire results on a scale from 1(Awful) to 7(Excellent) are presented in Fig. 9.

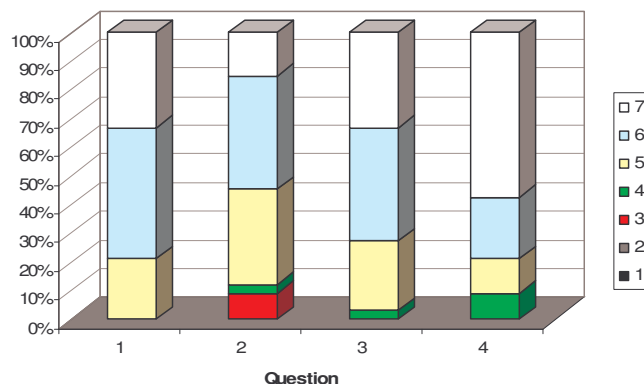


Fig. 9. Impact of the didactic test frame - student feedback

Comparing the average results obtained on a question on influence lines in the exams of 2006/2007 and 2007/2008 there was near 10% improvement. In addition student comments can be considered very positive as shown by the following samples:

- “Learning becomes easier and the lectures are more interesting”;
- “Visualization provides a practical link to the theoretical concepts which are more quickly perceived”;
- “We get a better feel for the structural behaviour”;
- “Seeing is believing”;
- “We should have one tool of this kind for each topic”;

- “This initiative is most welcome”.

We strongly believe that reinforcing this experimental teaching tool with the virtual one now being completed will provide a deeper learning setting that will lead to significant improvement in student performance in future years. This dual approach will be instrumental in effectively addressing the whole range of individual learning styles expected within a large student group [8, 9].

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ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of the University of Porto.