Distance learning earthquake engineering through shaking table tests and online tools

AMADEO BENAVENT-CLIMENT
Department of Structural Mechanics
University of Granada
Edificio Politecnico Fuentenueva, 18071 Granada
SPAIN
benavent@ugr.es

Abstract: - This paper presents an innovative educational project for teaching earthquake engineering, based on an enhanced distance learning system. An extensive use of online educational tools are proposed to motivate students' participation in dynamic tests and competition for predicting the responses. As an example of implementation, a recent experience at the University of Granada is described. Here, several shaking table tests on two half scale models are combined with numerical simulations aimed at predicting the observed response. Based on this experience, the advantages and practical problems from the perspective of engineering are identified. In closing, several recommendations are made for improving the results of the proposed teaching method.

Keywords: computer simulation; distance learning; dynamic tests; earthquake engineering; online; model.

1 Introduction

In many countries, the syllabus of architecture or civil engineering studies include learning to design structures in earthquake prone areas. Commonly, teaching structural analysis courses requires the inclusion of two thematic units: theory and experiments. In the case of earthquake engineering, the experimental part is especially important because, fortunately, students are not usually accustomed to experience earthquake loads. In contrast to gravity loads, destructive earthquakes have long return periods and students have sometimes wrong ideas: they tend to think that learning how to prepare structures for this type of accidental events is not that important.

The author believes that the best way to enhance the interest of the inexperienced students on learning earthquake engineering is to expose students to the physical behavior of a model structure subjected to an earthquake up to collapse, through shaking table tests simulated in a laboratory. This experience triggers out students' desire of knowing more about the phenomena, of learning how to predict the response and how to prepare the structure for such type of scenario. Studying the mathematical and mechanical theories which are indispensable to design structures against earthquakes is much more stimulating if the real phenomena can be observed in advance. Our experience proves that, the more involved the students are in the experiment, the more effective is the shaking table test as an educational tool. This involvement can be achieved giving the students the opportunity of participating during the preparation, and by providing the students with the detailed information about the test (i.e. characteristics of the model, earthquake wave to be used etc).

However, testing a structure in a shaking table up to collapse can be dangerous: it requires restricting the access to the laboratory and giving special attention to safety issues. In contrast to testing structural models under static loads, a shaking table tests cannot be carried out with the physical presence of inexperienced students. It is the technologies used in distance education that can play an important role. In this paper an innovative educational project for a distance learning of earthquake engineering is proposed. This project involves synchronous and asynchronous technologies. The proposal is grounded on an experience conducted at the University of Granada. The synchronous technology involves "video streaming" to transmit the real-time online broadcasting of the shaking table tests, which are taking place in the laboratory. The asynchronous technology consists of a web platform that allows students to: (i) participate in test preparation, (ii) download information measured during the test (i.e. history of acceleration measured in the shaking table etc.) —excepting the test results—; (iii) upload a prediction of the response of the tested structure carried out by the students using the theory that they have learned online with the guidance of the instructor; (iv) compare their prediction with the test results provided online; and (v) discuss the predicted and test results. This distance learning can be further enhances by organizing a "contest" among the students in which they compete in submitting the prediction of the response of the tested structure.

The idea for this educational project is based on three past studies. However, it should be noted that there is an important difference between these studies and our experience, because (1) the former used traditional, not distance, learning schemes, and (2) tested small models under static loads. The first study deals with a course in mechanical engineering at the Imperial College of London. The students developed a project with steel plates, beams and rivets, in which they had to span the distance between two points with a bridge, using the least material possible. The final experiment was conducted by the instructor, who had to walk across the bridge of the students. The second study explains the experience of the college of Architecture in Madrid, Spain. The students had to build a structure with small timber bars by themselves, and it was tested under gravity loads in a competition scheme. The third study was derived from an educational project conducted at the University Jaume I, in Spain [1]. It combined the use of a plastic toy called K'NEX and a well-know computer program for structural analysis.

American universities also used models as teaching tools. Setareh [2] describes a class in which a set kits of small-scale building components were used, accompanied by computer software that guided the user through the process of building assembly and construction. Behr [3] proposed a project in which computer simulations were compared in nearly real time with physical measurements made on bench-scale model experiment. Electronic sensor were employed to record the physical response of the loaded model, and numerical and experimental data were compared.

2 Problem formulation and scope

The educational experience described in this paper is aimed at: (i) motivating the inexperienced students of architecture or civil engineering that engage in the earthquake engineering for the first time; (ii) increasing the students' awareness of the importance of seismic design, (iii) showing the students that predicting the response of a structure under seismic loads is much more cumbersome that under gravity loads, because the response is largely within the inelastic range.

To achieve these objectives, the following propositions are formulated: (i) the active participation of the students in the preparation of the tests increases their level of involvement in the education process; (ii) observing first the physical phenomena makes easier understanding later the mathematical modeling and the underlying theories; (iii) experiments improve students' motivation.

The educational scope of the experience are architecture or civil engineering students without any background in earthquake engineering, except basic courses in solid mechanics and structural analysis. The syllabus for the structural analysis courses includes the principle of virtual work, the stiffness method, and basic dynamics of single and multi degree of freedom systems.

3 Development of the project

The project is organized in the following order:

1. Through the e-learning platform, the instructor proposes the type of structure to be studied and explains the objectives and possible constraints of the experiment (space limitations, maximum capacity of the shaking table etc). In the education experience conducted at the University of Granada, a flat slab supported on four steel columns was selected. The objectives were to observe the displacement pattern, the failure mode an the efficiency of including an innovative technology known as energy dissipating device (EDD). As for the constrains, the test model shall not exceed $3\times3\times2m^3$, and the shaking table could not be accelerated beyond $15m/s^2$.
2. An online discussion group is created on the e-learning platform for exchanging suggestions about the design of the test model, the test set-up and the instrumentation. The students exchange sketches and text files. The final test model is approved by the instructor.
3. After that, the physical model is prepared in the laboratory. To enhance the involvement of the students, they can follow the process of construction by using the video streaming technology. Figure 1 shows an image of the construction stage. The students can also "safely" participate in this process sending emails to the discussion group. In the education experience conducted at the University of Granada, two half-scale test models were built: the first one was a bare flat slab structure; the second was a similar flat slab structure with EDDs installed as diagonal bars. Figures 2 and 3 show the test models already instrumented and installed on the shaking table.
4. Once the test model is completed and installed in the shaking table, the instructor uploads the latest information about its actual characteristics,

material properties, set-up and instrumentation schemes to the e-learning platform. The date and time of the test is also announced online. It is worth noting that the final characteristics and properties of the test model always differ from the original drawing, and the students must be aware for conducting the predictions of the following steps.

5. The shaking table test is conducted in the laboratory and followed online and in real time by the students through the video streaming technology.
6. Through the e-learning platform, the instructor states the problem that the students must address in relation to the experiments, and provides them the additional data measured during the test that they need to solve the problem. Commonly, the problem stated consists in estimating some response parameter of the structure measured during the experiments. The students must conduct this estimation on the basis of their previous knowledge in structural mechanics, and the theoretical texts and assistance provided by the instructor. He also provides helpful "in house" software for conducting the prediction. This software is not intended to solve the problem, it only avoids the students from loosing time in secondary aspects and to concentrate on the neuralgic aspects of the seismic problem staged with the shaking table. In our experience at the University of Granada, the additional information provided by the instructor was the actual acceleration measured on the shaking table during the test. The problem stated was to estimate the maximum displacement of the slab. The "in house" software was a subroutine for calculating response spectra. The challenge for the students was to make the best approximation to the actual response measured during the test, which strongly relied in (i) choosing an adequate mathematical model for representing the specimen tested and (ii) identifying the locations where plastic deformations took place.
7. After giving the students a reasonable amount of time, the instructor asks them to upload their prediction to the e-learning platform, in form a brief report. Encouraging the students to write reports, makes the distance learning no only a way to transfer knowledge but also to enhance competence in communication skills and group work—an important goal of the European Space of Higher Education. The reports presented by each student or group of students, are uploaded in the web, so that each one can analyze the answer provided by his colleges.
8. A new discussion topic is opened on the platform, so that the students can discuss the results, and the appropriateness of the approach used by each student to make the estimation. In the education experience conducted at the University of Granada, one of the key issues that determined the goodness-of-fit was the estimation of the stiffness of columns and slab, and the damping of the system.
9. Finally, the students are asked to upload a brief report in which they evaluate (i) the solution submitted by their peers; and (ii) their own work. They are also encouraged to discuss how the solutions could have been improved.
10. On a competitive basis, after reading all the students' reports, the instructor selects the best solution to the problem stated. The experience at the University of Granada shows that the opinion of the students provides often valuable feedbacks to organize future experiences.

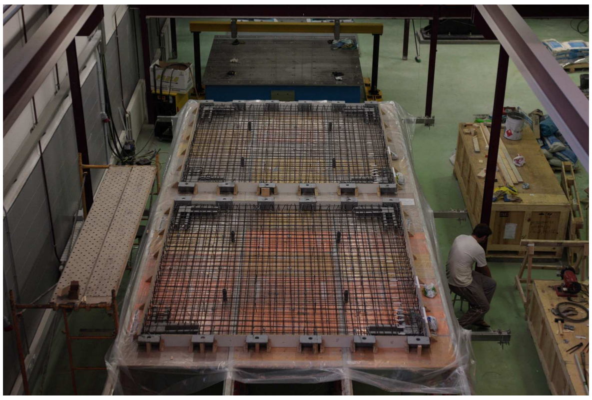

Figure 1: Process of construction of the test model

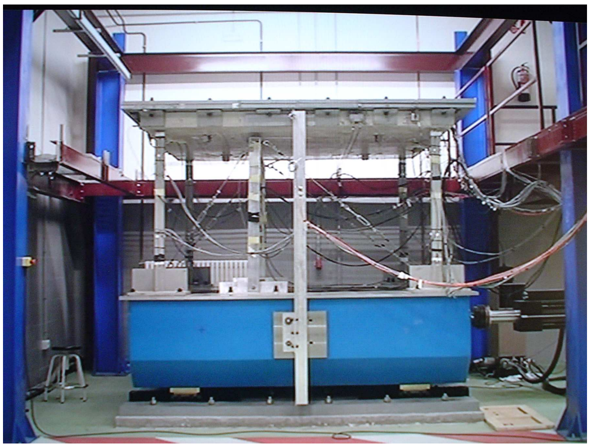

Fig. 2: First specimen tested on the shaking table

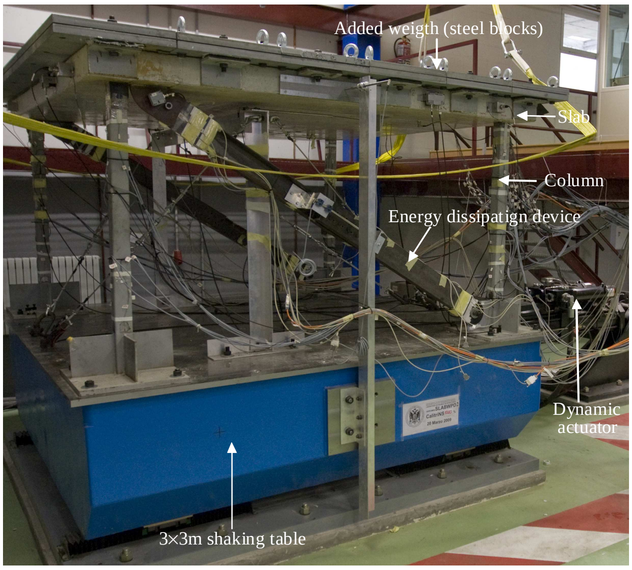

Fig. 3: Second specimen tested on the shaking table

4 Conclusion

In this paper, an innovative educational project for distance learning of earthquake engineering is proposed. It is based on enhanced e-learning tools that (i) stimulates the students' participation in designing and preparing the specimens; (ii) provides "real-time" observations of the actual response of a structure subjected to an earthquake up to collapse through a simulation on a shaking table; and (iii) encourage brain-storming on the prediction of some parameter of the response. The entire process consists of the web-based e-learning platform. The students observe the test though video streaming technology and predict the response with the knowledge acquired by the study of the theoretical texts uploaded by the instructor on the web, and basic "in home" software.

From the experience at the University of Granada, the main advantages of this educational approach of earthquake engineering are that: (1) the students are fully satisfied with this kind of experiments; (2) they understand better the theoretical aspects that underlie the physical phenomena; and (3) the special features of the earthquake loads, in comparison to gravity load, are fully acknowledged. The author would like to point out here that a significant number of students —larger than in previous years when this experience was not realized—decided to join advanced earthquake engineering courses taught in the University of Granada.

The main limitation of this educational approach is that it is expensive and requires sophisticated equipment. Furthermore, the results of the project might be improved by: (1) increasing the number and degree of complexity of the "in house" software provided online by the instructor to the students; and (2) making the students to calculate also the response by applying different seismic codes.

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