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A LEARNING BY DOING APPROACH IN TEACHING THE FUNDAMENTALS OF THE STRUCTURAL DESIGN OF TRUSSES

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ABSTRACT

This paper reports the findings of a study, conducted with second year students of civil engineering enrolled in the course of Engineering Mechanics at the Civil Engineering Department of Istanbul Kultur University, to improve the understanding of fundamental concepts related to the structural design of trusses. Students were asked to build truss systems from Balsa wood loaded with small weights, analize the truss member forces and indicate whether the members are under tension or compression. At the final stage of the workshop, a group discussion was held on the factors effecting the design of trusses with references to the structural models prepared by the students. In addition to supplementing the theoretical concepts related to the analysis and design of truss systems, preparation of the physical models and experimentation with the educational analysis software have also increased the motivation of the students towards the course of Engineering Mechanics.

Key Words: Civil Engineering Education, Trusses, Learning by Doing.

INTRODUCTION

Trusses are essentially triangular assemblies of slender pin-connected straight structural elements, typically made of metal or timber and are widely used for crossing large spans. Structural members of a truss are subjected to either compression or tension when external concentrated loads are applied at their nodes. Trusses are preferred over full sectioned structural systems when it is particularly desirable to reduce the self weight of the structure. A sound understanding of the working principles of trusses is not only essential for the analysis and design of truss members but is also helpful for the comprehension of relatively complex structural engineering concepts, such as the strut and tie mechanisms of deep reinforced concrete beams and masonry walls.

Structural analysis of trusses with pin connections is initially covered within the scope of the course of Engineering Mechanics, which is a second year course in the curriculum of the Civil Engineering undergraduate program at the Istanbul Kultur University. The course of engineering mechanics is conducted in two sessions per week, a 4 hour theoretical session and a 2 hour problem solving session. The subject of trusses is expected to be covered in two weeks.

Conventional classroom delivery of the subject of trusses typically covers the definition of a truss, classification and of truss systems, basic assumptions used in the analysis of trusses with pin connections, determinancy of trusses as well as the analytical and graphical methods used in the structural analysis of trusses. Although, students may also experiment with standardized truss kits when such laboratory sets are available, the mode of delivery of the subject primarily relies on classroom lectures and problem solving sessions. Therefore, students tend to focus on the problem solving aspects of the lectures in order to prepare for the exams which may reduce their motivation and their desire to gain a deeper understanding of the subject.

This paper reports a set of complementary exercises that aim to support the theoretical discourse on the analysis and design of trusses, though a "learning by doing" approach which is widely used in engineering and architectural design education (Yazici and Erkan Yazici, 2013).

CLASSROOM DEMONSTRATIONS WITH EDUCATIONAL SOFTWARE

Conventional classroom delivery of the theoretical and practical aspects of the structural design of trusses, was enriched with the use of educational computer programs of ForcePad and Pointsketch2D. ForcePad is a simple and program which provides insight on how loads are transferred in structural components (Division of Structural Mechanics, Lund university, 1999). Students can easily draw arbitrary 2D shapes, apply structural restraints, forces or displacement and observe the distribution of stresses and the deformed shape. ForcePad is also capable of demonstrating the basics of truss optimization.

In the classroom demonstration, ForcePad was used to show the distribution of loads in a simply supported rectangular plane section subjected to a concentrated load at the midspan. It was observed that there are compression zones between the concentrated load and the structural supports. It was also observed that there is a tension zone between the pin support on the left and the roller support on the right (Figure1a). Afterwards, optimization features of the ForcePad was used to abstract the shape of a simple truss that students are quite familiar with. Students were also briefly informed on the strut and tie mechanisms in plane elements and how their structural response can be estimated with simple analytical models using truss analogy.

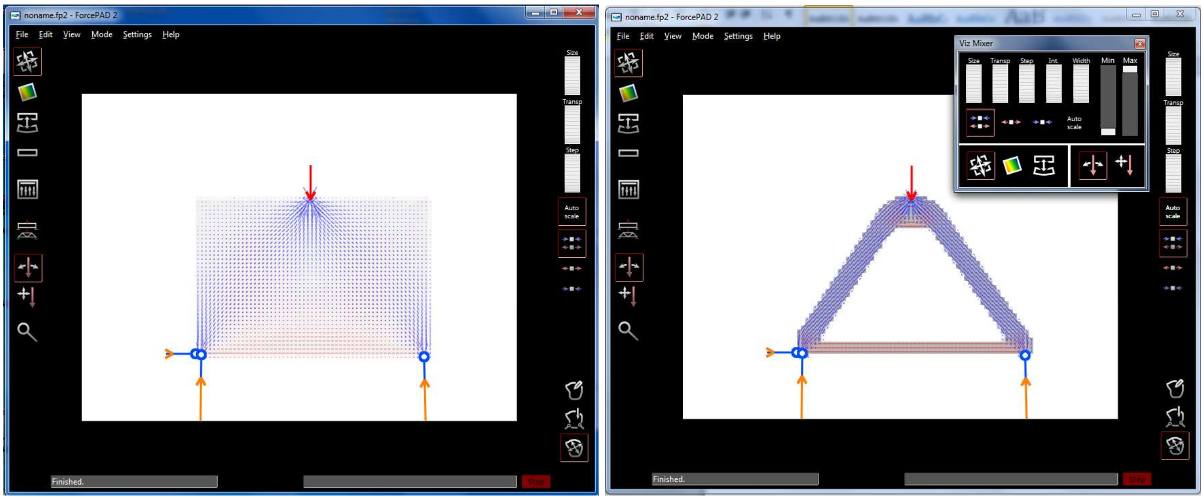

Figure 1: (a) Stress distribution due to the concentrated load at midspan (b) Strut and tie abstraction created by the truss optimization feature of ForcePad

Pointsketch2D was selected as the educational structural analysis software for supporting problem solving aspects of the lectures on trusses (Olsson, 2006). Pointsketch 2D was also particulary useful in demonstrating how truss systems deform under forces. After a very brief demonstration on the use of Pointsketch2D, students were asked to verify the results of the hand calculations of their homework assignments on trusses with this software. Structural analysis results and the deformed shape of a simple truss obtained from Pointsketch 2D is shown in the Figure 2.

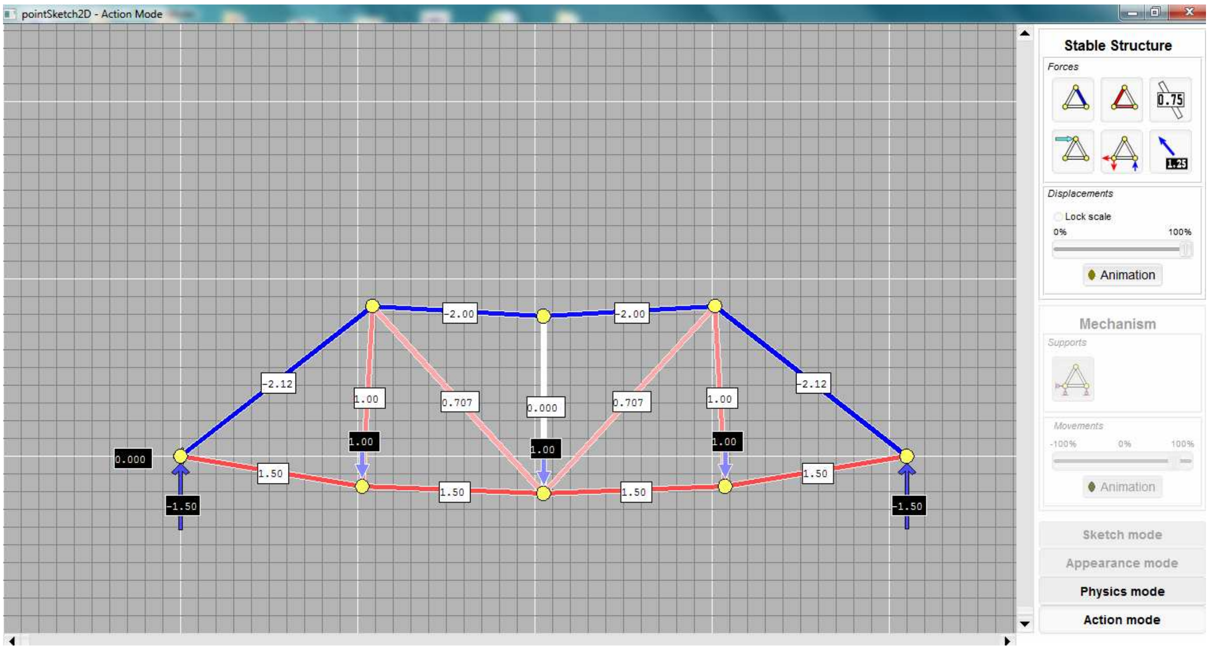

Figure 2: A screenshot of the structural analysis results generated by Pointsketch2D

COMPLEMENTARY WORKSHOP EXERCISE

Experimentation, even with small scale models, can provide insight on understanding design issues which may arise in real life construction applications, in addition to increasing the physical understanding of engineering design problems. A workshop exercise which involved building and testing small scale truss models with voluntary participation of a limited number of students. Truss models, made of balsa wood, were built at the architectural model workshop of the Faculty of Architecture and later loaded with small weights (Figure 3).

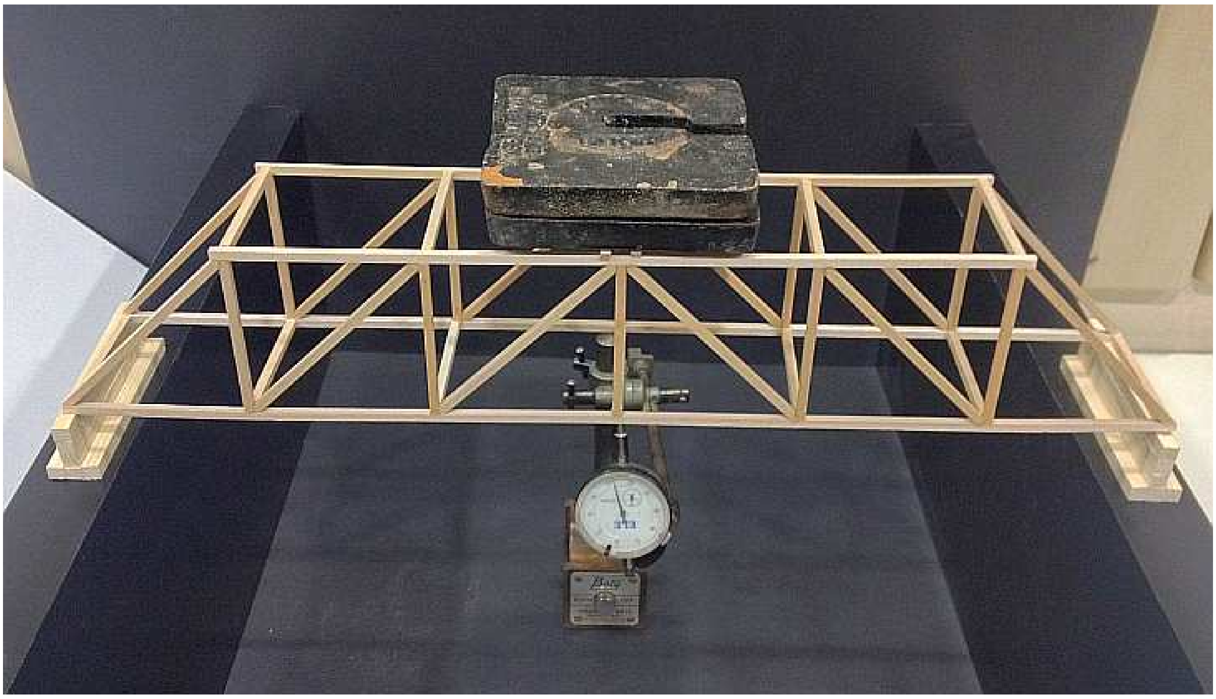

Figure 3: Testing of small scale truss models

Preparation of the construction drawings with CAD software and the use of model building equipment were side benefits of this exercise. Model building process lead students to focus on issues such as the design and construction of connections, material imperfections and dimensional tolerances (Figure 4).

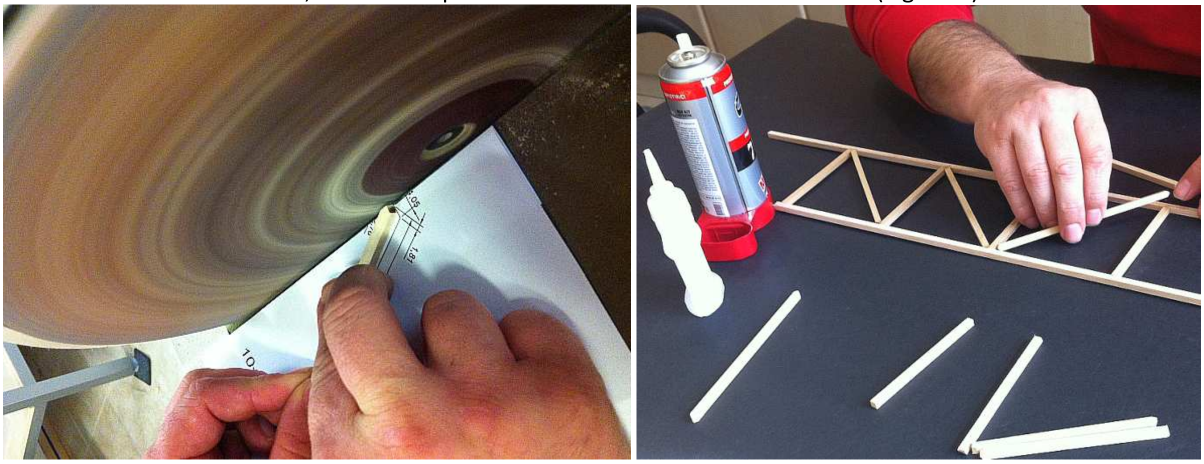

Figure 4: (a) Construction of a connection using model building equipment (b) Model assembly

In addition to conventional truss models made of balsa wood with glued joints, modular truss models made of PVC members (Figure 5) or a combination of balsa wood and PVC members (Figure 6) have also been constructed in order to obtain truss systems with pin connections.

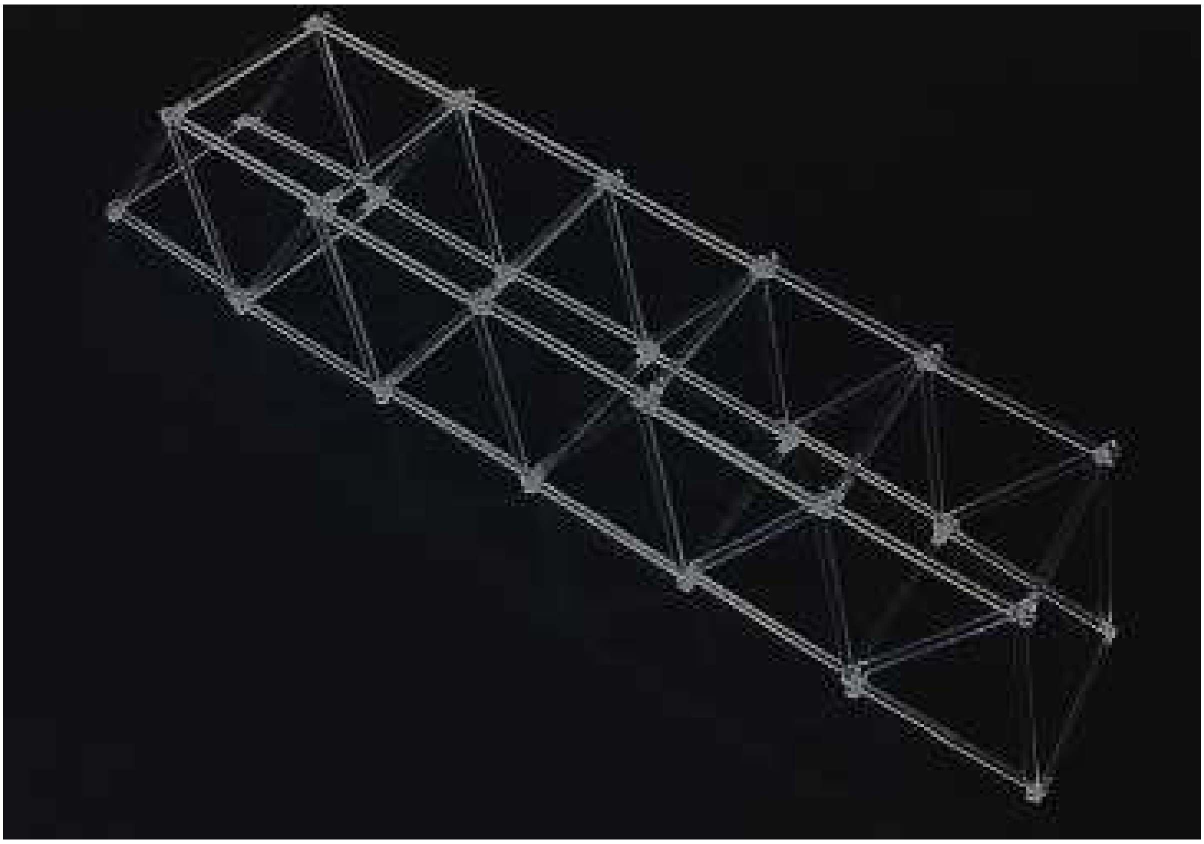

Figure 5: Truss model with pin connected PVC members

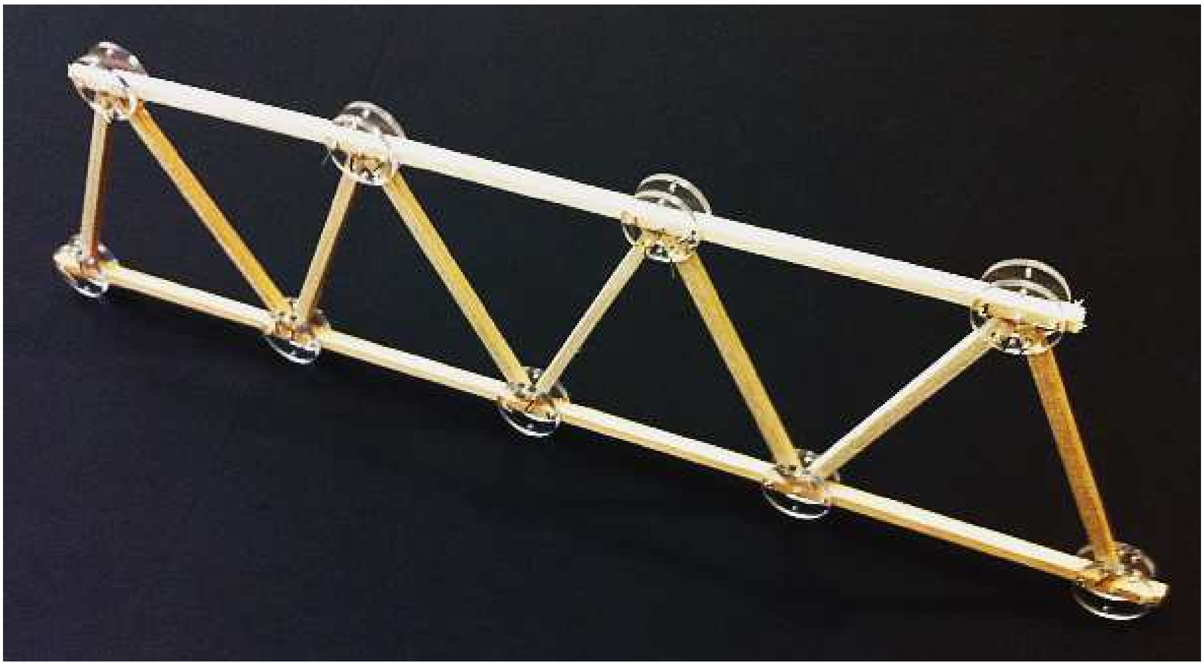

Figure 6: Truss model with pin connected diagonal members

PVC components have been cut out of 0,30 cm thick PVC plates using the laser cutter at the architectural model workshop of the Faculty of Architecture (Figure 7). Although, these models have not been tested with loads, they have been extremely useful in demonstrating the response of pin connected truss systems and some of problems which may arise during the detailing of pin connections.

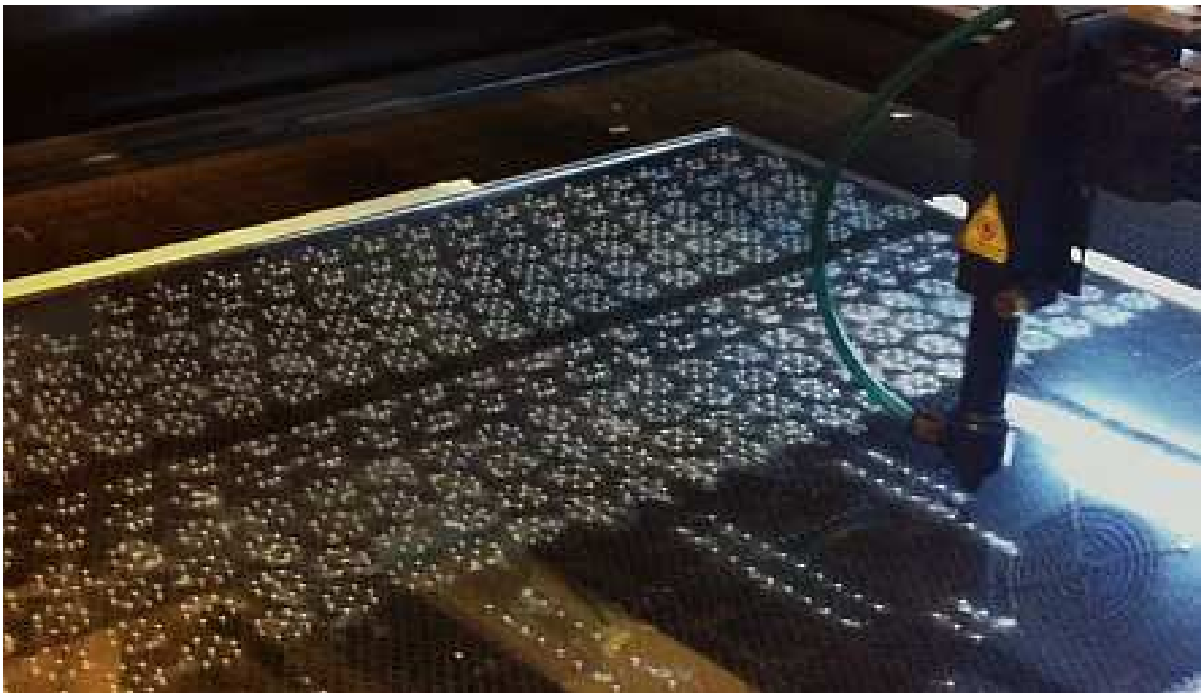

Figure 7: Preparation of the PVC components with the laser cutter

At the final stage of the workshop, a group discussion was held on the factors effecting the design of trusses with references to the structural models prepared by the students.

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CONCLUDING REMARKS

The course of engineering mechanics embodies the study of forces and their effects on rigid bodies and is considered as a fundamental course in the undergraduate curriculums of civil engineering. This is due to the fact that the concepts covered within the scope of this course are essential for laying out the foundations for the vast majority of civil engineering analysis and design courses. Complementary exercises with educational software and physical models outlined in this paper can help facilitate the understanding of the theoretical concepts presented in the lectures. Working with physical models also had the added benefit of increasing the familiarity of students with computer aided drafting and manufacturing technologies, which is actually quite important since civil engineers have to take into consideration the available construction materials and manufacturing capabilities when designing structural systems (Seckin et al., 2013). Engineers also have to use hand calculations in the development of the initial structural design plans and during the verification of the results obtained from refined computer aided analysis. Therefore, combined use of hand calculations, computer aided analysis tools and manufacturing technologies outlined in this study makes contact with essential elements of the structural design cycle.

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