Introduction of a "project" component into the sophomore-level "Statics: Basic Mechanics" course

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Abstract

Engineering programs in the United States are faced with the challenging problem of decreased retention rates at the undergraduate level. The focus on theory is one, among several factors that has been identified as a possible reason for students losing interest in completing their chosen engineering degree. The capstone course attempts to create a balance between theory and practice, and exposes students to the practical side of engineering. However, it is offered during the final year of the undergraduate program and does not influence retention rates in the earlier stages of the program. In this light, this paper describes a novel "project" component that has been incorporated into a sophomore year "Statics: Basic Mechanics" course, which is a core requirement across all disciplines. The goal of this paper is to describe the structure and scope of the project, so that it can be replicated and incorporated into a variety of different freshman and sophomore level engineering courses.

Keywords

Retention, Engineering, Statics, Hands-on, Project

Introduction

The United States requires qualified engineers and is faced with the challenging problem of not producing an adequate number of engineering graduates. It has been shown that obtaining a college education is correlated with attaining financial success[1]. It is well known that retention rates in engineering programs are declining[1,2,3], and lie in the range of 40-60%.

Research shows that high attrition rates in engineering programs are partly attributed to the programs being theory-intensive and lacking a practical, hands-on component in the earlier years (freshman and sophomore years)[4,5,6,7,]. Consequently, it has been found that most attrition occurs during this period.

This paper presents a project component that has been implemented into the sophomore level core course "Statics: Basic Mechanics 1" at the author's institution. The idea to include a project into this course arose as a consequence of a request to the author made by a group of sophomore-year "Honors" students to complete a project related to trusses in the aforementioned statics course. As a part of the Honors program, honors students are required to work in groups of two students on a project related to a course of their choice. They have the ability to “stack” courses and do research on the course’s topics.

“Statics” is a theory-based course in which systems in equilibrium are analyzed using the equations of static equilibrium. However, the project described in this paper adds a hands-on, experiential learning component to this ordinarily theory-focused course. The enthusiasm, excitement and motivation displayed by these students over the course of the project reflects that the inclusion of a hands-on component into “Statics” could potentially serve to increase the level of interest and involvement that students feel toward this ordinarily theory-focused course, and dissuade them from withdrawing from it. **An interesting aspect of this exercise is that it serves to demonstrate the application of the classroom knowledge in “Statics” to a real-world project, and also exposes the participants to the use of commonly used state-of-the-art computer tools which they would ordinarily not be exposed to in “Statics”**

Project

This section describes the details of the system to be analyzed by all the students as part of the project. Figure 1 is an elevation view of the bridge truss that was used in this project, based upon the construction drawings provided by the engineer. Figure 2 is a plan view of the floor system, also obtained from the construction drawings.

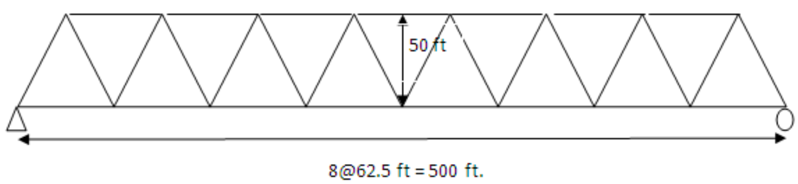

Figure 1: Elevation view of truss

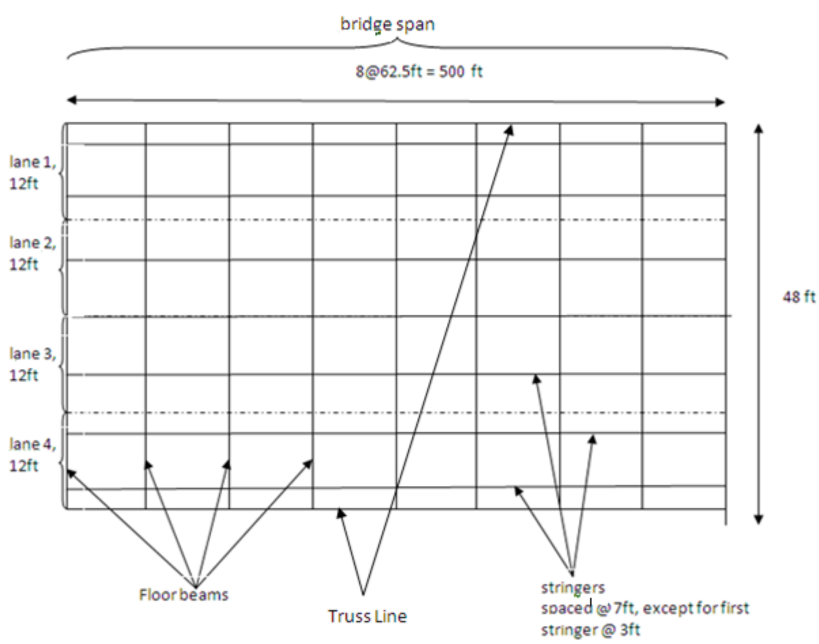

Figure 2: Plan view of the floor system

The relevant features of the structural model used in this project are presented below:

- W33*169 stringers were used in the floor system. The floor beams comprised built-up I sections, whose web and flanges were comprised of plates. The flange plate dimensions were 2.25" in. thickness and 36 in. width, and web plate dimensions were 7'2" in. height and 0.75" in. thickness.

- The vertical design loads and the load combinations that were used were obtained from the AASHTO LRFD Bridge Design specifications. A 640 lb-force/ft live load was used. The load was uniformly distributed across the width of each lane. Hence, a total live load of 640*12 = 7680 lb-force was applied on each lane. The location of the live load on a lane causing the maximum effects (shear and moment in the supporting stringers) was identified using the influence line concept. This resulted in the maximum point force applied at the joints on the bottom chord of the truss.

- The dead load was computed using the following dimensions and densities of the materials comprising the floor system:

  Density of concrete deck = 150 lb-force/cubic foot;

  Density of steel = 490 lb-force/cubic foot;

  Thickness of concrete deck = 8 inches.

- The dead and live loads were combined using the following load combination:

  Combined vertical load = $(1.2)(Dead\ Load) + (1.75 \times 1.25)(Live\ Load)$

  The bridge was located in southern Kentucky, on the border with Tennessee. The Kentucky code recommended multiplying the live load was multiplied by a factor of 1.25, in addition to the standard code recommended 1.75 factor.

- The trusses were pin supported at one end and roller supported at the other.

- The floor beams and stringers were pin supported at both their ends.

- The floor beams were connected to the bottom chord of the trusses at each panel point (that is, every 62.5 feet).

- The first stringer was placed at a distance of three feet from the truss line.

- The weight of the truss bars was neglected in the structural analysis of the truss. All truss joints were approximated as pinned joints.

Methodology

The project exposes students to a variety of different computer tools that they will use in the future as engineers. It will also require them to design a 3D model of an engineering structure that they are learning about in the classroom, to load it in the laboratory in order to visualize its response under load and consequently be introduced to experimental work, to perform hand-calculations based upon classroom principles in order to analyze its response, and to develop a computer model of the system under scrutiny on a state-of-the-art software tool, against which the accuracy of the hand-calculations can be checked. This will expose them to a combination of hands-on activity, theory, and the use of computer tools, thereby giving them a well-rounded idea of the classroom knowledge and will assist in retaining their interest in persisting in the engineering program. The project involves the following components:

1) Proposal Development: Students were asked to prepare a proposal in collaboration with the author to obtain funds to purchase the material needed to successfully complete the project. The relevance of the project in the context of retention in engineering programs was explained to them. The overview of the procedure to be followed to execute the different stages of the project was discussed. Based upon this information, they developed a draft proposal which was reviewed and edited by the author. This proposal was submitted to obtain funding in response to a “Request for Proposals” internal to the author’s institution.

This process exposed students to the process of developing a proposal which involved clearly explaining objective of the project, the background information pertaining to the proposed work, the uniqueness of the project, its significance, the method of execution and the budget. This knowledge is useful to engineers, whether they work in academia or in the industry. Additionally, the exercise of writing the proposal in the context of engineering education introduced them to this field, which they might feel inclined to pursuing in the future.

2) Literature Review: This activity involved collecting all relevant data about trusses: the history of trusses, when they were first used, why they were first used, their significance and uniqueness, their advantages and disadvantages relative to other commonly used structural systems, and some innovative, real-world applications of trusses in construction.

This exercise provides students with knowledge and information about trusses that is not covered in the classroom. By venturing outside the basic information contained in the textbook, and investing time in thinking more about a structural system that they are studying in the classroom and its history, and the impact that it has had on society over the course of its use in construction, students might be better able to appreciate the relevance of the material that they are studying in the classroom. Also, thinking creatively about the interesting developments in the field of engineering in history that led to the introduction of an innovative structural system such as a truss, can help them better appreciate the level of thought and effort that has been invested in their chosen discipline over the years. Analyzing a truss’ pros and cons can help them learn to think critically and apply this type of thought to develop innovative additions to existing structure in the future. Going beyond the textbook forces them to push themselves and develop as intellectuals. Finally, on a more practical level, it teaches them how to perform background research on a topic, and how to summarize the relevant information into a concise, free-flowing and easily comprehensible form. This training will be useful to them in the future, whether they choose to work in the industry, or academia as researchers.

3) Hand-calculations: Following the literature review, students apply hand-calculations to perform a structural analysis of a bridge truss (described in the “project” section earlier) and the

stringers and floor beams in the bridge floor system, using fundamental principles of "Statics" taught in the classroom. The truss is analyzed using two theoretical methods: the method of joints and the method of sections.

The structural system that was used for this purpose was obtained on consultation with a bridge engineer in the industry, who provided the author with construction drawings of an actual project that he worked on. This provided the author with realistic values for the loads acting on the bridge, the size and spacing of the stringers and floor beams in the floor system and the thickness of the bridge deck, the material used to construct these components, the dimensions and configuration of the bridge and the bridge trusses, and support conditions of the system.

This exercise builds the students' theoretical foundation and gives them confidence in their ability to understand their classroom knowledge better. Additionally, it exposes them to a real-world engineering project, and displays the significance of the knowledge that they learn in the classroom. It also gives them confidence in their ability to apply their theoretical knowledge in solving a real-world engineering problem. Students can lose confidence in themselves when they are constantly studying abstract and challenging theoretical concepts, and sometimes feel apprehensive about their ability to grasp all this material and eventually work as engineers. By completing a real-world project of the sort described, students gain a sense of self – confidence in their abilities, and learn that they are indeed capable of functioning as engineering professionals once they graduate. A sense of self confidence helps them persist with their chosen major instead of withdrawing.

By performing the structural analysis of the system, students learned about concepts such as design loads, load combinations, influence lines, load path (path followed by the load from the bridge deck to the stringers to the floor beams to the bottom chord joints of the truss to the supports), and tributary area, in addition to applying method of joints and sections to analyze the truss. These are very important concepts in structural engineering.

4) Finite Element Analysis (FEA): In this stage, after being a general qualitative overview of the fundamental concept of finite element analysis, they develop a model of the bridge truss on ANSYS[8]. ANSYS is a finite element analysis tool for structural analysis, including linear, nonlinear and dynamic studies. This computer simulation product provides finite elements to model behavior, and supports material models and equation solvers for a wide range of engineering design problems. The students perform a structural analysis of the truss on ANSYS, and check the results of their hand-calculations against those obtained using the software model.

This exercise exposes them to the use of a software tool commonly used in the industry, teaches them how to develop computer models of structural systems, and also introduces them to the finite element analysis methodology. Once they learn to use one structural and analysis package, it makes it easier for them to learn others based upon this experience.

5) Development of final 3D model: In this stage, students develop a scaled down, 3D model of the bridge they analyzed. The model comprises the bridge trusses showing the individual bars pinned together at gusset plates, the bridge deck, the stringers and floor beams, and the pier supports. The model is developed using a combination of two tools: SOLIDWORKS[9], and a 3D printer. SOLIDWORKS is a computer-aided design (CAD)–based solid modeler, and utilizes a

parametric feature-based approach to create models and assemblies and runs on Microsoft Windows. The geometric model of the truss is developed on SOLIDWORKS. Subsequently, the SOLIDWORKS file is printed out using a 3D printer, using Acrylonitrile Butadiene Styrene (ABS). The students were asked to research the material that would be compatible with the 3D printer and to order it at the lowest cost that they could find. The material was purchased using the grant money that funded this project.

This exercise exposes students using both SOLIDWORKS and a 3D printer, both being very useful tools to be familiar with. Once the 3D real-life model is developed, the students are able to visualize the concepts and theory related to trusses discussed in the classroom with greater ease, as opposed to just learning about them theoretically.

Conclusions

Engineering programs face a high rate of attrition. Research states that introducing hands-on components into freshman and sophomore level courses can help to retain students. This paper described the introduction of an innovative “project” component into a sophomore level course titled “Statics: Basic Mechanics 1” and the benefits of such a course to students. This project was only recently added to the statics course and it would be useful to obtain feedback from students enrolled in this course, after the project component has been implemented over a period of a few years.

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Biographical Information

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