2006-650: PROJECT-BASED LEARNING IN ENGINEERING MECHANICS: INSPECTION AND ANALYSIS OF A HISTORIC TRUSS BRIDGE

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Project-Based Learning in Engineering Mechanics: Inspection and Analysis of a Historic Truss Bridge

Abstract

The civil engineering program at Western Kentucky University (WKU) is a project-based curriculum. Students have opportunities to engage in real project activities in order to develop an understanding of civil engineering practice. Projects are chosen that support student engagement, where the role of the students is as learners, observers, assistants and practitioners. For example, in a sophomore level mechanics course at WKU, engineering students worked in teams to perform a preliminary physical field inspection and analysis of a historic steel truss bridge located in Bowling Green, Kentucky.

The focus of the paper is to present the work performed by the students and how the project was integrated into the course curriculum where the concepts of engineering mechanics discussed in class were related directly to the bridge. Students appreciated this approach to learning which offers a unique hands-on experience where students actively participate by working in the field on an existing structure.

I. Introduction

In recent years, there has been a growing trend in engineering education to include project-based learning in the classroom. Numerous engineering projects have been incorporated into the classroom including the egg drop catcher and the balsa wood bridge projects to name a couple[1]. The general purpose of these projects was to demonstrate what is learned in the classroom and to encourage creativity and teamwork. Most of the projects attempt to simulate a development, design and analysis experience. While there is value to this approach, there is a greater need to expose students to real life engineering projects rather than a simulated project. Unfortunately, real life engineering projects are typically left to the senior capstone course[2,3]. However, engineering students upon entering college need exposure to real life projects to better prepare themselves as future engineering practitioners[4].

Practice based projects should be an integral part of engineering courses and should be spread out over all four years of the undergraduate program not just during the senior year in a capstone design course. This approach will better prepare students for engineering practice where basic concepts taught in the classroom are directly related to real life engineering problem. It is important for engineering students to understand that the study of engineering by nature is both academic and practice based. In the past several decades, greater emphasis has been place on academic studies[5].

Students in an academic setting typically have ample opportunity to become proficient in the pencil and paper rigor of engineering problem solving. However, there is a disconnect between academia and engineering practice[6]. The classroom learning environment is typically a passive experience such as in a lecture hall (with the exception of the laboratory courses), whereas engineering practice is an active experience. Students in a classroom setting need more active and engaged experiences[7]. Real life engineering projects encouraging active participation and physical exposure to real structures such as buildings and bridges can significantly improve student understanding of the applied principles of engineering mechanics and help bridge the gap between engineering education and practice. One such project involving an inspection of a historic truss bridge is discussed herein.

II. Historic Truss Bridge Project

Students working in teams actively participated in a class project involving a preliminary inspection of a local steel truss bridge. A dead load analysis of the truss superstructure based on as-built conditions was performed.

College Street Bridge

College Street Bridge is a four-span, steel, truss structure which crosses the Barren River in Bowling Green, Kentucky (see Figures 1 and 2). Spans 1 through 3 are through trusses, and span 4 is a pony truss. The historic bridge was built in 1915 and presently serves as a pedestrian bridge. The top chord truss members and the vertical truss members of the through trusses are made of built-up riveted steel sections. The lower chord truss members and the diagonal compression members of the through trusses are steel eyebars which connect to steel pins at the joints. The slender tension diagonals are steel bars with a circular cross-section. The members of the pony truss are built-up riveted steel sections.

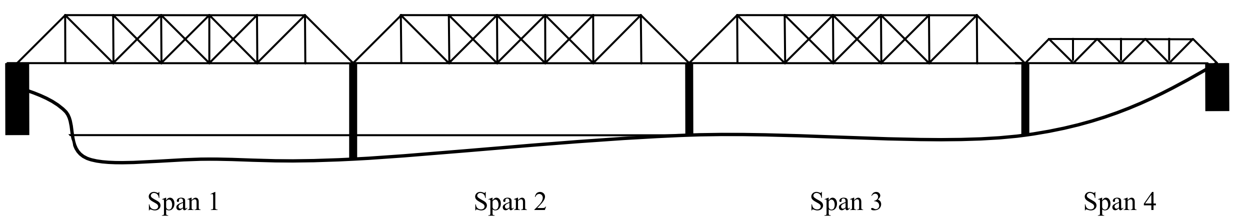


Figure 1: Elevation View of College Street Bridge

Figure 2: College Street Bridge

The Project

The purpose of the project was to give students an opportunity to work hands-on on a real engineering structure, to see and feel members and joints of a real bridge. Students were required to perform a preliminary inspection of the truss superstructure, spans 1 through 3. This involved three components: basic bridge geometry (since plans of the structure do not exist), member properties, and locating notable areas of deterioration. Basic bridge geometry included length of truss (lower cord), distance between panel points, lengths of vertical, diagonal and bottom chord members, transverse distance between trusses (centerline to centerline), and roadway width. Member properties included size and shape as well as cross-sectional area. Notable areas of deterioration included pitting losses and impacted rust.

One of the challenging aspects of such a project is the proper integration into the statics curriculum. This is discussed in the next section.

III. Project & Course Integration

While there are many topics in engineering statics, the key components are as follows:

- Particle and rigid body equilibrium
- Centroids and centers of gravity
- Forces in beams and cables
- Analysis of trusses, frames, and machines
- Friction
- Moments of inertia

At the beginning of the course a significant amount of time is spent on particle and rigid body equilibrium, approximately one-third of the semester. However, I believe this is time well spent since many of the other topics are directly related. Thus, near the end of particle and rigid body equilibrium, the students are given simple assignments to introduce themselves to the bridge and to develop an understanding and hopefully an appreciation of the history of the structure. Specifically, the students are required to individually visit the structure several times to gather information such as information from bridge plagues and to draw a sketch of the bridge. In addition, students gathered information from the internet.

At this point, the structure is discussed in greater detail using a MS PowerPoint presentation with hands-outs to show the different components of the structure. Homework problems relating to the structure are given for emphasis. The goal of the project is not only to introduce the students to a real physical structure but to improve the students' understanding of many areas of engineering statics, specifically:

- Introduction to structural members (truss members and beams such as floorbeams)
- Introduction to connections (such as pins or bearing connections)
- 2D and 3D equilibrium
- Particle equilibrium (such as at a joint)
- Methods of joints
- Method of sections
- Loads on beams and trusses
- Internal forces in beams and trusses

Upon completion particle and rigid body equilibrium, forces in beams and analysis of trusses are discussed. During this time, topics relating to simple trusses such as truss rigidity, zero force members, compression members, tension members, methods of joints and sections are emphasized and related to the bridge. Approximately at mid-semester, students in teams of three or four visit the bridge during two consecutive class periods to perform a preliminary inspection. During the inspection, bridge geometry and member properties are noted. The results of this are discussed in the next section.

In the final portion of the project, the student teams performed a dead load analysis of the truss superstructure. The teams had to calculate dead load forces and stresses in selected members of the truss.

III. Students in the Field

Students performed a preliminary hands-on inspection of the College Street Bridge, spans 1 through 3. Inspection was performed from complete access to the top of deck. Top cord members were visually inspected from the top of deck. Field measurements were taken to determine member geometry as shown in Figures 3 and 4. Truss nomenclature for spans 1 through 3 is shown in Figure 5. From the measurements, cross-sectional area for each member

was calculated and is shown in Table 1 with the respective member length. In the field, minor areas of member deterioration due to pitting losses and impacted rust were found.
Using the method of sections and joints, students computed member forces for selected members. Calculating the weight of the truss members and approximating the weight of the floorbeams, stringers, bracing members and deck, students determined the dead loads on the structure, which were then distributed to the respective joint as a joint dead load. Having calculated the joint loads, the students performed a dead load truss analysis of the structure for selected members. Knowing the forces and respective cross-sectional areas for select members, corresponding stresses were found, which are shown in Table 2.

Figure 3: Students Measuring Section Properties of a Vertical Truss Member.

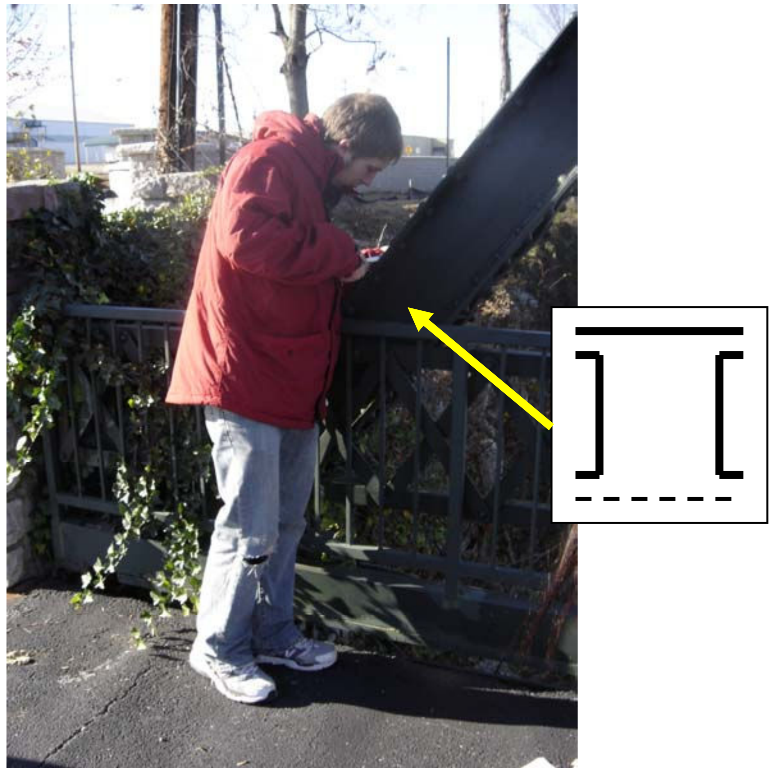


Figure 4: Student Measuring Section Properties of a Truss Diagonal

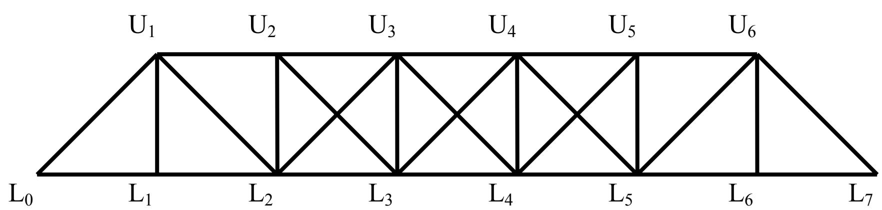


Figure 5: Truss Nomenclature for Spans 1, 2, and 3.

Table 1: Truss Member Geometry for Spans 1, 2, and 3.

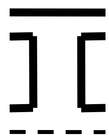
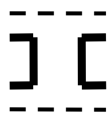
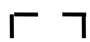
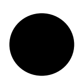
Member	Schematic Cross-Section	Cross-Sectional Area (mm^2)	Length (m)
L_0-U_1, U_1-U_2, U_2-U_3, U_3-U_4, U_4-U_5, U_5-U_6, U_6-L_7		14,050	L_0-U_1, U_6-L_7 = 8.00 All others: 5.18
U_2-L_2, U_3-L3, U_4-L_4, U_5-L_5		4,330	6.10
U_1-L_2, U_6-L_5, U_2-L_3, U_5-$L_{4,}$ L_0-L_1, L_1-L_2, L_5-L_6, L_6-$L_{7,}$		3,900	U_1-L_2, U_6-L_5, U_2-L_3, U_5-L_4 = 8.00 All others: 5.18
L_2-L_3, L_3-L_4, L_4-L_5		7,780	5.18
U_1-L_1, U_6-L_6		1,875	6.10
L_2-U_3, L_5-U_4		805	8.00
L_3-U_4, L_4-U_3		1,575	8.00

Table 2: Selected Member Forces and Stresses

Member	Force† (kN)	Stress† (MPa)
L_0-U_1	-240	-17.08
U_1-L_2	161	41.28
U_1-U_2	-261	-18.58
L_1-L_2	163	41.79

†A positive value denotes tension, and a negative value denotes compression.

IV. Summary & Conclusions

In a sophomore level engineering statics course, a project was integrated into the curriculum. The project involved a preliminary inspection of the superstructure of a historic steel truss bridge. Truss geometry and member properties were measured in the field. In addition, minor areas of deterioration were documented. The information was used by the students to perform a dead load truss analysis of the structure for selected members.

In general, the students really enjoyed the project especially the visits to the bridge. Through a course integrated project which involved a significant hands-on experience, students learned to relate engineering concepts discussed in class to a real structure.

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