FREE BODY DIAGRAMS – AN ASSIGNMENT FOR A BASIC TOPIC

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1. INTRODUCTION

This paper explains an out of class, group assignment covering the topic of free body diagrams. The assignment makes use of a landmark pedestrian cable stayed bridge located on campus. A photograph of the bridge, as presented on the engineering design company website (Engineering Resources) is shown as Figure 1. While free body diagrams are an elementary topic in any statics course, the topic is also absolutely essential. The basics of identifying "the body" are critical before any calculations using the equilibrium conditions can be employed. Nevertheless, what makes "the body" of the free body diagram can often be overlooked due to the simple structural models used in elementary aspects of the subject matter. This paper explains an assignment developed to encourage students to take a more critical look into just what "the body" is for a free body diagram.

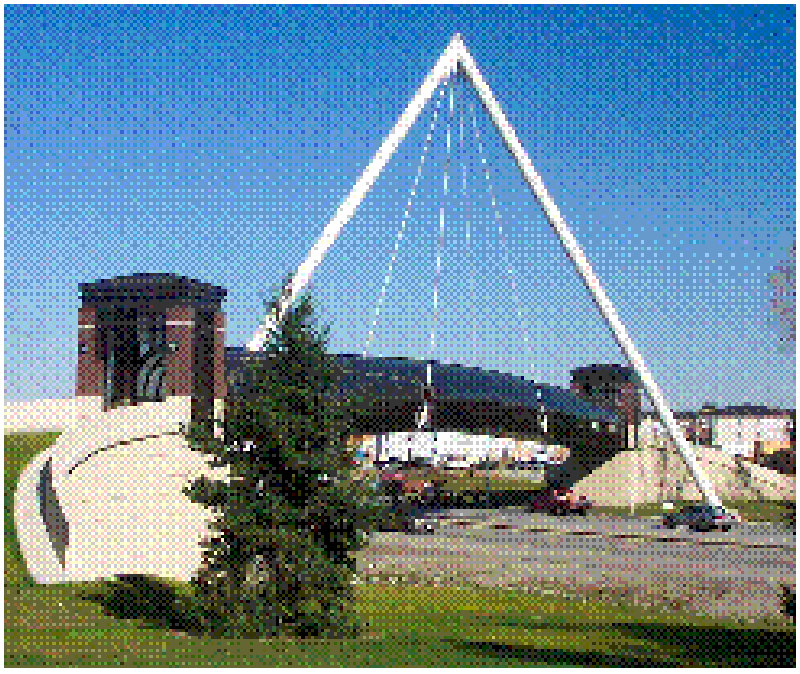

Figure 1.
Photograph of Cable Stayed Bridge
The Willis Family Bridge over Crescent Avenue

The essence of the assignment is for students to collaborate with each other to determine just what makes the free body diagram for the bridge. Students are introduced to the concepts of free body diagram subject matter in class lecture. The assignment is made subsequent to this introduction of the subject matter.

The assignment has been used during the past two course offerings. Undoubtedly there are ways the assignment can be improved. Reaction from colleagues has been positive. Student response to the assignment has been mixed. The learning achieved from the assignment has not been quantified but is characterized in qualitative manners. The intention is to continue to develop and use the assignment and eventually institute metrics to assess student learning.

2. ASSIGNMENT DETAILS

The assignment is an early part of the class CET 181, Applied Structures I at Indiana University Purdue University Fort Wayne. This class involves subject matter usually associated with a first course in statics and has a prerequisite of mathematics at the level of algebra and trigonometry and a course in physics covering mechanics. The textbook currently used for the course is Applied Statics and Strength of Materials by Spiegel and Limbrunner. The course is required for students in the associate of science degree programs of architectural engineering technology and civil engineering technology. The course was initially developed by the author during participation in the Engineering Engineering Education, often referred to as E^3, A Catalyst Workshop for Change, conducted at Bucknell University in July 2004. The E^3 workshop focus is on active student centered learning activities and is funded by the National Science Foundation.

The intention of the Free Body Diagram assignment (FBD) is to serve as such an active student centered learning activity. At a minimum, FBD is an out of class activity for the student. Ideally, FBD enables student learning in the basics of statics.

FBD is given to students in the fourth week of the semester following the first examination. The subject matter covered on the first exam relates to mathematics, units, and the concepts of force. Students are arranged into teams of three based on their grades of the first examination. Students are not informed how the teams are determined. The student with the highest grade is put with the student with the lowest grade and the student who is closest to the average grade. Subsequent teams are formed with the second, third, etc. persons from each extreme along with the next nearest student to the average grade. Teams comprised of two students near the middle grade are preferred to teams of four students.

Students become aware of the assignment when an assignment sheet is distributed in class and photographs of the bridge are shown. The assignment sheet is included as Appendix A. The teams are then announced and students are asked to sit with their teammates to get acquainted. The assignment sheet is read and discussed point by point in class. Students are informed that the assignment is open ended such that there is not one correct answer but several correct responses along with similarly several incorrect responses.

Students can read directly from the FBD sheet that "the purposes of this assignment are for students to assess what makes a free body diagram and for students to work together in groups. Students should benefit by discussing the assignment as well as expressing themselves verbally, orally, and graphically in regards to the assignment." The instructor encourages discussion with other teammates and with other teams rather than respond directly to any question about the assignment or what the answer or response of the students should be. The instructor invites students to join a field trip to the bridge during a future class.

The intended response of students is for the teams to visit the bridge all together and take photographs and make sketches of what they think the bridge free body diagram is. Then students would resolve their various free body diagrams with one free body diagram that they all together determine is the best. The task is not trivial. The bridge is a real world object that students can look at and walk across. It is a 3-Dimensional object. The free body diagrams common in the course and in most of the textbook are all 2-Dimensional objects. The bridge has many components such as pylons, cables, earthen abutments, and a walkway enclosure. Each side of the concrete deck is supported by visible steel beams. Furthermore, the bridge is statically indeterminate and the supports at the abutment are not visible. Savvy students can contact the campus physical plant to view design plans and the design engineer does have some information about the bridge on the company's website (Engineering Resources). Nevertheless, the how to resolve a best free body diagram for the team is not evident.

Students have approximately two weeks, five class sessions, to complete FBD and the site visit tour to the bridge is scheduled two class sessions prior to the due date. Great care is taken to not directly inform the students of what the instructor considers to be the free body diagram of the bridge. During the site visit tour verbal mention of what is observed such as the concrete deck rests on the steel beams located to each side of it, that the steel beams are held up by the support cables, that the support cables are held up by the pylons, and that the pylons are bolted to large blocks of concrete resting on the ground. Questions are asked aloud such as "does the canopy walkway cover mean anything to the real structure of the bridge", "does a perspective from the end, side, or inside make any difference", and "what type of reaction supports exist". No answers are provided but students are encouraged to discuss the questions and resolve the answers in their teams.

3. OUTCOMES

Student submissions include the FBD sheet as a cover page, copies of the various free body diagrams developed for the assignment, the one best free body diagram as determined by the team, and written responses to various questions. Each student makes an individual submission that includes a rating of the other team partners. No student has refused to complete the assignment and no student has submitted work resembling last minute efforts. Student responses have been varied from very good to acceptable. The real critiques in grading are if a structural element is included in the free body diagram and a force that represents that structural element is also included. A penalty of one or two points is assessed for that type of mistake depending on the manner that the force and structural element are presented. This penalty accounts for either 5% or 10% of the assignment grade.

Numerous free body diagrams of the bridge are possible but three examples of a free body diagram for the bridge are most evident. Figure 2 presents a free body diagram comprised of only the bridge deck. The earthen abutments are represented as forces acting on the bridge deck and the cables are also represented as forces but pulling up on the bridge deck. The pylons are not a part of this free body diagram. Figure 3 presents a free body diagram comprised of the bridge deck and the cables as structural elements of the bridge. The earthen abutments still support the bridge deck and are represented as forces but now the pylons are represented as forces pushing up on the cables. Figure 4 presents a free body diagram with structural elements of the bridge deck, cables, and pylons. Forces represent the abutments supporting the deck and concrete blocks supporting the pylons.

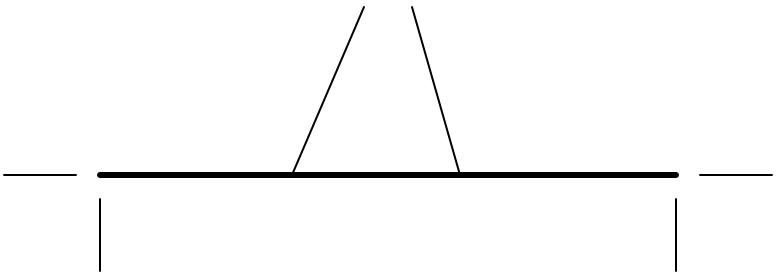

Figure 2
Free Body Diagram
Bridge Deck Only

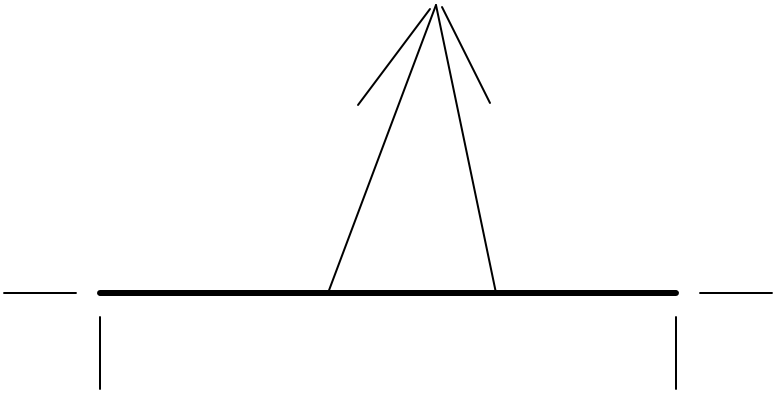

Figure 3
Free Body Diagram
Bridge Deck Only

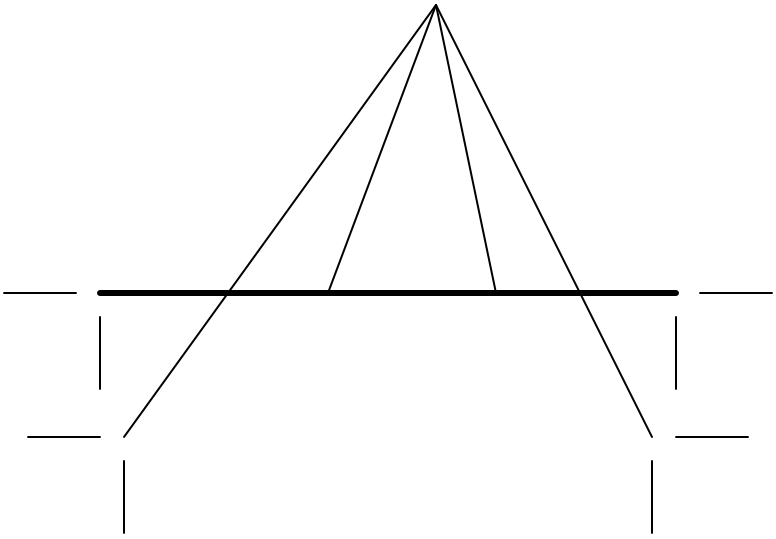

Figure 4
Free Body Diagram
Bridge Deck Only

The ultimate selection of any free body diagram is not important to the assignment grading. The reasoning, teamwork, and process used for the assignment is important. Thus the intention is that most all of the points associated with the project are earned by completing the assignment. Critiques are written on the student submissions and corrections are made to false statements but in most cases no penalty is assessed. The assignment is the

learning opportunity to have students more fully learn the subject matter. The grading of the subject matter occurs during exams. Thus if the student has not learned the subject matter well enough during this assignment as shown in the submission, the poor grade may occur at a later time. Either the student learns from the critiques and comments provided back to the student, learns from consultations with other students upon review of their graded work, or else the student likely scores a low grade on any exam question that involves free body diagrams.

Students have generally expressed contentment with the assignment. Students do enjoy the assignment particularly because it is not an ordinary assignment. The assignment sheet seems to create a sense of importance in the student's minds. Student learning has not been quantified in any manner as of yet.

Faculty colleagues who teach the subject of statics have commented about the assignment. These comments have all been quite positive. However, no other instructor has yet used the assignment in their class.

4. CONCLUSION

The FBD continue use is planned by the author when teaching CET 181. Improvements to the assignment will be investigated and implemented. Consideration is being made to require a minimum number of free body diagrams for each team. Furthermore, this issue of how to form questions with correct answers in the student's minds is being deliberated. Consideration of the types of loadings that occur on the bridge may be added in the future. The author would like to encourage other instructors to use such an assignment and relate the outcomes in an e-mail or through a similar publication or presentation. A formal quantitative assessment of the learning achieved by the assignment is a desired future improvement to the assignment. A review of similar assignments and learning objectives available in literature would be a component of this formal assessment. This would involve development of the assignment and recognition of formal learning objectives more than just learning free body diagrams and having students identify the "body".

REFERENCES

Engineering Resources, Inc., company website, www.erwebsite.com, http://www.erwebsite.com/Featured%20Struct%20Projects/IPFW%20Ped%20Bridge.htm, last accessed the 25th January 2006.

Spiegel, L. and Limbrunner G. F. (2004). Applied Statics and Strength of Materials. Pearson Prentice Hall, New Jersey.

Appendix A
Assignment Sheet

CET 181, Fall 2005 Group Letter: _____
FBD Assignment (20 points)

Your name: _____ Group member name: _____

Group member name: _____

The purposes of this assignment are for students to assess what makes a free body diagram and for students to work together in groups. Students should benefit by discussing the assignment as well as expressing themselves verbally, orally, and graphically in regards to the assignment.

- Work together with class members assigned to your group.
- Travel to the bridge over Crescent Avenue that connects the IPFW academic campus with the Waterfield Campus student housing area. This is the Willis Family Bridge.
- Look at the bridge in sufficient detail to recognize the different parts (structural elements) that make up the bridge. Make sketches and take photographs if that will help you remember what you are looking at. Travel to the bridge as many times as needed.
- Discuss with your group what structural elements make up the bridge. You may also talk with other students in the class and any other person such as other faculty members in the CAET Department, engineers, construction workers, or any person at all.
- Discuss what structural elements make up a free body diagram (FBD) of the bridge. Each group should develop multiple FBDs and discuss the relative merits of each. Discuss the forces that exist on the bridge. Discuss the types of reactions that exist on the bridge. Discuss what structural elements make up the bridge and what you see that is not a structural element of the bridge.
- Decide, as a group, what structural elements make up the bridge. Resolve in your group the one FBD that best represents the bridge. Draw this best FBD and scan or copy it for each group member.
- Prepare an individual, written (typed or word processed) report that includes
  - a listing of the various structural elements seen when observing the bridge,
  - an explanation why these structural elements either are or are not part of the bridge,
  - a discussion of the types of forces that act on the bridge,
  - a description of the various FBDs considered in the assignment,
  - written text describing what, if anything, you learned from this assignment,
  - written text describing what, if anything, was difficult about this assignment,
  - a description of each group members input & rate involvement on a scale of 1 to 10,
  - attach scans or drawings of your group's best FBD and other FBDs considered,
  - a clear explanation of the FBD that you believe best represents reality and why,
- Submit your individual report with this sheet as a cover page on 12 October 2005.
- This is an open ended assignment. There is no single correct answer or response to this assignment. Different Free Body Diagrams and writing may be correct.

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