Project Assignments for Statics

Developed by:
Rebecca Atadero, Department of Civil and Environmental Engineering, Colorado State University
Meena Balgopal, School of Education, Colorado State University
Darrell Fontane, Department of Civil and Environmental Engineering, Colorado State University
Karen Rambo-Hernandez, Learning Sciences and Human Development, West Virginia University

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Introduction

The project assignments included in this document were used in addition to a traditional lecture based statics course in our research. However, these assignments can be adapted to fit a variety of course styles. We provide additional details of our course here to give an example implementation and context for some of the assignment requirements.

The three assignments presented here correspond to three units used to organize the semester:

1. Equilibrium (sum of forces=zero, sum of moments = zero)
2. Applications of Equilibrium (beams, trusses, machines)
3. Miscellaneous topics (moments of inertia, friction, virtual work)

The project was assigned at the beginning of the unit, students received traditional lecture during the unit, and at the end of the unit student groups had to present their designs to the class. Midterm exams were also held at the end of each unit.

In class we presented these projects as design opportunities for the students. On the second day of the semester, the instructor described the engineering design process to students and then assigned the first group project. For each project students were given one in-class meeting of about 20-30 minutes, the remainder of work was expected to be completed outside of class.

Students completed these assignments in groups of five. The course enrollment was approximately 110 students. Two-hour evening time periods traditionally used for exams were used for groups to present their design projects to the rest of the class.

Project 1: Design and Build a Rube Goldberg Machine
Demonstration: (date and time)

What:
Wikipedia defines a Rube Goldberg Machine as "a deliberately over-engineered or overdone machine that performs a very simple task in a very complex fashion." In this project students will work in teams of 5 to design and build a Rube Goldberg machine.

Machine Requirements:

1. The objective or purpose of your machine is to display a team flag, thus the last step in the machine must end with a flag (of any size) being displayed, waved, etc.
2. The machine should have at least **five steps** or operations, each member of the group should be the design engineer responsible for one of the steps.
3. The machine will need to be demonstrated to the class. Thus it needs to be portable and able to be quickly set-up.
4. The components of the machine should operate on principles that can be described with statics – the operation should not depend on high speeds, impact or momentum.

Design Report Requirements:

1. Teams must prepare a report detailing how the Engineering Design Process (as discussed in class) was followed in design of their machine.
2. The report should describe preliminary conceptual planning of how different components might work together.
3. The report should include a 1 page diagram that shows each of the major steps in your machine, with some indication of the statics principles involved at each step.
4. The report must include a detailed analysis of the operation of each component. This analysis should be based on the principles of statics learned in this course, and include free-body diagrams and mathematical computations. Each student in the group should be the design engineer preparing the drawings and computations for one component of the machine. The design engineer for each component should be clearly indicated on the relevant pages.
5. The report should describe changes and adjustments made to the design during construction to enhance its performance.
6. At the end of the report each group member should attach a self-reflection with two short paragraphs describing 1) what the student learned about statics from the project and 2) what the student would do differently if they received a similar assignment in the future (this could be something technical , something related to group work, any type of change).
7. The report should be a neat, organized and thorough documentation of project work.

Top Three Machines:
On demonstration day students in class will vote for their favorite machine. The top three machines will be videotaped in action and the videos will be placed on the College of Engineering website.

Project 1 Rubric

Team # __________ Group Members:____

Machine

			Score
Displays a Flag			
Flag is clearly displayed (it is lifted, it waves, it pops up, etc) (5 pts.)	Flag is present, but not effectively displayed (e.g. it gets stuck, or is kind of hidden) (3 pts.)	Flag is not displayed (0 pts.)	
Includes at least 5 components			
2 points per component up to 10 points			
Works during demonstration			
Machine runs smoothly without aid after starting (10 pts.)	Machine needs one or two small interventions (7 pts.)	Machine requires many interventions, does not work (0 pts.)	
Operates on principles of statics			
All components can be described with statics (5 pts.)	One or two components cannot be described with statics (3 pts.)	More than two components cannot be described with statics (0 pts.)	

Report

			Score
Describes conceptual planning			
Report describes how the team arrived at the idea for each component and how the components work together (5 pts.)	Report describes how the team developed individual components but not how they work together (3 pts.)	Not included in the report, or very poor description. (0 pts.)	
1 page diagram showing machine operation			
Diagram shows all components and describes the statics principle behind each component (5 pts.)	Diagram shows all components, but does not explain principles behind operation (2 pts.)	Not included in the report, or very poor diagram (0 pts.)	
Analysis of each component : Free Body Diagrams			
Appropriately isolated a portion of the component for analysis, and included all forces (3 pts. per component)	Isolated body, but missing forces (1 pt. per component)	Does not fully isolate a body for analysis (0 pts. per component)	

Analysis of each component: Mathematical computations			
Correct application of equilibrium equations with real weights, dimensions etc. (3 pts. per component)	Correct application of equilibrium equations without real quantities (2 pts. per component)	Incorrect application of equilibrium equations (0 pts. per component)	
Changes and adjustments made to the design			
Describes changes made to the design during construction. Compares computed quantities to the quantities that actually work. Identifies sources of difference/error or limitations of the analysis (10 pts.)	Describes changes made to the design. Some comparison, or discussion of error – but limited detail (no explicit calculations, no clear definition of sources of error). (5 pts.)	Describes changes made to the design with no additional discussion. (1 pt.)	
Neat, organized, professional			
Text is typed. Drawings are very neat and use a straight edge. Pages are in the correct order. Report shows organization (uses headings, for example)(10 pts.)	Report is hand written. Drawings are clear, but not especially neat. Limited organization. (5 pts.)	Report text and drawings are sloppy. Report has very little or no organization. (0 pts.)	
Self -reflection page			
2 points per group member with decent effort answering the two questions listed on the assignment page, 1 point per group member with limited effort.			

TOTAL SCORE: ___________/100

Suggested Modifications for Project 1

- When this project was used during the pilot semester with in-lecture presentations, students came up with designs that they could easily transport around campus. When projects were presented in the evening, outside of the normal class time, students produced much more elaborate designs. Depending on the presentation context, it might be a good idea to include a time limit for set-up of the machine and perhaps a limit on the size of the machine.

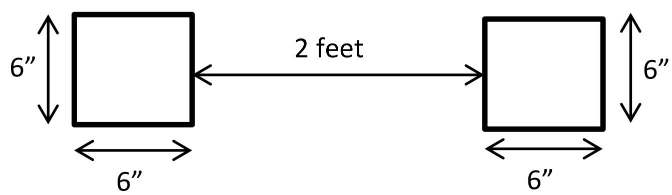
Project 2: Design and Build a Truss Bridge

Objective:

In this project teams will design and construct a bridge using only wood and string. Bridges will be load tested in class. The objective is to carry the highest load with the least material, while meeting the design constraints listed below. Teams will also need to prepare a report that describes how they applied the engineering design process to their bridge design and includes analysis of their design and of the bridge failure.

Design Constraints:

1. For load testing the bridge must rest on the support platforms which will be arranged as shown below:



2. The bridge must allow for a loading device to be **hung from the centerline** of the bridge.
3. The bridge must be free-standing. (A planar truss will not have the necessary stability.) The bridge cannot be anchored to the supports with string.
4. Each team will be provided with six 3’x(3/16)”x(3/16)” pieces of bass wood. You do not have to use it all, but you cannot use more.
5. Teams may use an unlimited amount of string, but the string must be the string provided by the professor and TA.
6. No glue or adhesives are allowed.

Judging:

Bridges will be loaded in class. The formula below will be used to rate the bridges:

$$Bridge\ Rating = \frac{Total\ Load}{2(total\ length\ of\ wood) + (total\ length\ of\ string)}$$

The bridge with the highest rating will be declared the winner. In order to receive credit for using less wood or string than provided, extra segments of material must be turned in.

Timeline of Important Dates:

Monday 10-1-12	Project assigned, New groups assigned
Friday 10-5-12	Time for group work in class
Monday 10-15-12	Drawings of truss designs due in class
Wednesday 10-24-12	Bridge load testing in the evening, Prediction due at time of testing
Monday 10-31-12	Analysis of bridge failure due

Design Report Requirements:

The report for this project will include three separate components:

1. Bridge Drawing – due 10-15-12

An accurate drawing of the bridge design (showing plan and elevation views) must be produced. This drawing can be done carefully by hand, but if you are familiar with a CAD package you are encouraged to use it. Your drawing must clearly indicate how the design can be loaded by hanging a loading device at the center line. These drawings will be used to ensure the loading device will work for all teams.

2. Description of Design Process and Prediction – due 10-24-12

Teams should prepare a description of the process followed in the design and construction of their bridge. The report should describe preliminary conceptual planning of how the loads could be supported with different arrangements of members. The report should include a complete analysis of your bridge. This analysis should identify which members will be the most highly loaded. You should use your analysis to predict how the bridge will fail. The report should describe any changes or adjustments made to the design during construction.

3. Analysis of Failure and Reflection – due 10-31-12

After load testing each group must take their broken bridge and analyze the failure. This portion of the report should describe how the bridge failed using the best of your knowledge. Questions to answer might include: Was your prediction correct? Why or why not? Did anything unexpected happen? Did your bridge act effectively as a truss? Did bending or shear play a role in the failure of the bridge?

At this time each group member should attach a self-reflection with two short paragraphs describing 1) what the student learned about statics from the project and 2) what the student would do differently if they received a similar assignment in the future (this could be something technical, something related to group work, any type of change).

All components of the report should be a neat, organized and thorough documentation of project work.

Project 2 Rubric

Team # _________ Group Members:____

Bridge

			Score
Stable and Self-supporting			
Bridge can be placed on supports quickly and then loaded without any interventions from the team (10 pts.)	The bridge must be gingerly placed on the supports and the team may have to intervene to keep the bridge upright at the start of loading (5 pts.)	The bridge is not stable and self-supporting (0 pts.)	
Uses only provided materials			
There is no evidence that additional materials or adhesives were used (5 pts.)	There is evidence of additional materials or adhesives (0 pts.)		

Design Drawing

			Score
Loading Point			
The loading point is clearly indicated on the drawing and is compatible with a hanging load device (5 pts.)	The loading point is indicated on the drawing, but is not compatible with a hanging load. (2 pts.)	No loading point indicated. (0 pts.)	
Neat and Professional			
Drawn neatly in a CAD package or by hand with a straight edge. Dimensions are labeled. Includes at least 2 different views of the bridge. (5 pts.)	Drawing is neat, but lacks some details such as dimensions or different views of the bridge. (2 pts.)	Drawing is very sloppy and lacks detail (0 pts.)	
Accurate representation of constructed bridge			
The drawing is representative of the constructed bridge with only minor differences (5 pts.)	There are significant differences between the constructed bridge and the drawing (2 pts.)	The constructed bridge does not resemble the drawing at all. (0 pts.)	

Design Process and Prediction

			Score
Describes conceptual planning			
Report describes in detail how the team decided on the configuration of the bridge and how to make use of the materials. (5 pts.)	Report describes how the team decided on the general configuration of the bridge, but with less detail (3 pts.)	Not included in the report, or very poor description. (0 pts.)	
Detailed Analysis of Bridge Forces			
Calculations are provided showing the internal forces in each member of the bridge. (15 pts.)	Internal forces are determined for some pieces of the bridge, but not all members. (8 pts.)	Internal forces are not determined. (0 pts.)	
Analysis Assumptions			
Assumptions for analysis are clearly explained (5 pts.)	Analysis assumptions are listed, but not explained. (2 pts.)	Analysis relies on assumptions, but no assumptions are described.(0 pts.)	
Failure Prediction			
Report includes a prediction of how/where failure will occur and explains why this prediction was made. (5 pts.)	Report includes a prediction of how/where failure will occur without any justification (2 pts.)	No prediction is made (0 pts.)	
Changes and adjustments made to the design			
Describes changes made to the design during construction, and why these changes were necessary (5 pts.)	Describes changes made to the design without further explanation (2 pts.)	Does not describe changes made to the design (0 pt.)	
Neat, organized, professional			
Text is typed. Drawings are very neat and use a straight edge. Pages are in the correct order. Report shows organization (uses headings, for example) (5 pts.)	Report is hand written. Drawings are clear, but not especially neat. Limited organization. (2 pts.)	Report text and drawings are sloppy. Report has very little or no organization. (0 pts.)	

Failure Analysis

Failure Description			
The failure is clearly described with text and drawings or figures to aid explanation (5 pts.)	The failure is described without figures, or figures are used but the written description is poor (3 pts.)	A poor description of failure without figures (1 pt.)	
Rationale for Failure			
An explanation for the failure is provided drawing on course material and including calculations (10 pts.)	An explanation for failure is provided without specific supporting information (5 pts.)	No explanation for the failure is provided (0 pts.)	
Neat, organized, professional			
Text is typed. Drawings are very neat and use a straight edge. Pages are in the correct order. (5 pts.)	Report is hand written. Drawings are clear, but not especially neat. Limited organization. (3 pts.)	Report text and drawings are sloppy. Report has very little or no organization. (0 pts.)	
Self -reflection page			
2 points per group member with decent effort answering the two questions listed on the assignment page, 1 point per group member with limited effort.			

TOTAL SCORE: __________/100

Suggested Modifications for Project 2

- The presentation/bridge loading evening was an underutilized learning opportunity when we implemented this project. Students observed how different bridges failed, and the instructor heard some very good comments from students during the presentations. This learning could have been formalized though an assignment requiring students to comment on the failures of different bridges or through a structured group discussion.
- It may be worthwhile to instruct students to design bridges that they have the tools to analyze. We had some very creative bridge designs that could not be analyzed with just the statics skills students had. Alternatively, the fact that some bridges could not be analyzed with just statics could have been better leveraged as a chance for students to reflect on the limitations of their current knowledge.
- Many students were frustrated with only using knots for connections. Other connection materials could be used with a higher loading ability.
- Our loading technique was not very fast and made the presentation evening long and slow. The means of applying load is worth detailed consideration.

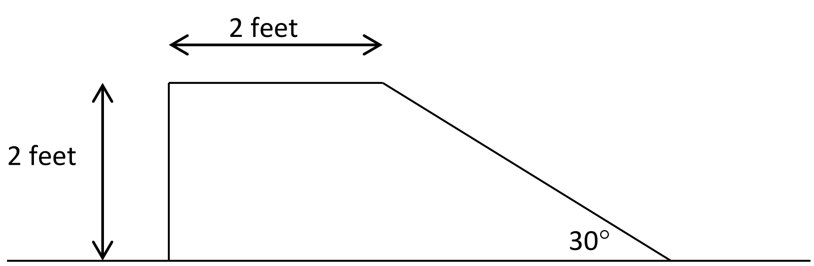
Project 3: Friction

During the first group project many teams commented about the generally negative effect friction was having on the accuracy of their analysis and the operation of their machines. However, there are also many situations where a machine, piece of equipment, engineering system or process relies on friction to make it work.

Objective:
The objective of this project is for each group to use friction to their advantage to move a CSU ram to the top of the "mountain". There are a variety of different ways that friction can be of use to you. I encourage you to be creative in your choice(s). Sections 6/4 through 6/9 of your textbook include some example applications of friction calculations that might help you come up with an idea, but if you have another idea feel free to use it – variety will make our class demos fun.

Your process to get the ram to the top does not have to be a self-operating machine, it is perfectly acceptable for it to be a hands-on process. You just need to be able to describe and calculate how friction is helping the ram climb the mountain.

The Mountain:
The mountain will have the dimensions shown below. It will have a depth into the page of 1.5 feet. It will be constructed of plywood. You may take advantage of any side/surface of the mountain to get the ram to the top.



Class Demonstrations:
Groups will demonstrate their application of friction in the evening from 5-7pm on Wednesday December 5th in Clark A201. Groups will be limited to a total of 5 minutes for set-up, explanation, and demonstration. If your group learns something interesting about friction or statics while you are working on this project please share it with the class during your presentation.

Report:
Each group must prepare a <u>short</u> report which:

- Describes how friction is essential to their process for getting the ram to the top.
- Includes calculations using real (or at least realistic) numbers to describe the process.

- Explains with words and calculations how the situation would be different if friction did not exist or was very limited.
- Includes a short reflection from each group member answering the questions: 1) what the student learned about friction from the project and 2) what the student would do differently if they received a similar assignment in the future.

Project 3 Rubric

Team # __________ Group Members:____

Demonstration

			Score
Ram Gets to the Top			
The ram gets to the top of the mountain using the method the group intended (10 pts.)	The ram gets to the top of the mountain, but it is clear things didn't go as planned (7 pts.)	The ram does not get to the top of the mountain (0 pts.)	
The process applies friction			
Friction is a very important part of the process (10 pts.)	Friction is involved, but is not the primary means for moving the ram (5 pts.)	The involvement of friction is incidental. (0 pts.)	
Explanation			
The explanation of the process is very clear and emphasizes how friction is important to achieving the goal (10pts.)	The explanation generally makes sense, but there are some confusing parts and/or it does not emphasize the role of friction (7 pts.)	The explanation is very limited/poor. Friction is not really discussed. (0 pts.)	
Group Work			
All members of the group are active in the demonstration, either by helping with explanation or conducting the process (10 points)	Most of the group members are active in some way (7 pts)	The demonstration is dominated by one or two people (0 pts.)	

Report

			Score
Describes how friction is essential			
Report describes in detail how their process for getting the ram up the mountain depends on friction and explains how friction is helpful (10 pts.)	Report provides a cursory explanation of how friction is essential to the groups process (5 pts.)	Not included in the report, or very poor description. (0 pts.)	
Calculations with Friction			
It is clear what is being calculated and why. The calculations use real numbers. They include FBDs (20 pts.)	Calculations are provided but it is not very clear why they are meaningful (14 pts.)	Calculations have major inaccuracies and the significance of the calculations is not at all clear. (5 pts.)	
Without Friction			
Report describes how the situation would be different without friction and provides some calculations to back up the description. (10 pts.)	Report describes how the situation would be different but does not include any calculations (5 pts.)	Not included in the report (0 pts.)	
Neat, organized, professional			
Text is typed. Drawings are very neat and use a straight edge. Pages are in the correct order. Report shows organization (uses headings, for example)(10 pts.)	Report is hand written. Drawings are clear, but not especially neat. Limited organization. (5 pts.)	Report text and drawings are sloppy. Report has very little or no organization. (0 pts.)	
Self -reflection page			
2 points per group member with decent effort answering the two questions listed on the assignment page, 1 point per group member with limited effort.			

TOTAL SCORE: __________/100

Suggested Modifications for Project 3

- This assignment description does not put enough emphasis on students conducting outside research on friction. Also students need to be encouraged to use friction creatively, possibly with credit assigned to creativity in the rubric. We had many projects that were very similar.
- Students seemed a little burned out by the end of the semester. This project could be skipped, reduced in scope, or presented with great emphasis or enthusiasm to help improve student response.