Project #2 – Structural Modeling: Design, Optimization, and Teamwork

Project Description

The following project requires participants to use good planning, teamwork, and engineering problem solving techniques. The overall objective is to design and build a new building structure that meets or exceeds minimum specifications supplied by the customer while maximizing overall profit. The following information explains the specific objectives of the project.

The design process should be a tool for the engineering student to use when approaching design problems and should guide them from design specifications to a final solution. While there are many design structures that could be implemented, the iterative design structure will be used for this project. See Figure 1 for the steps involved in the engineering design process.

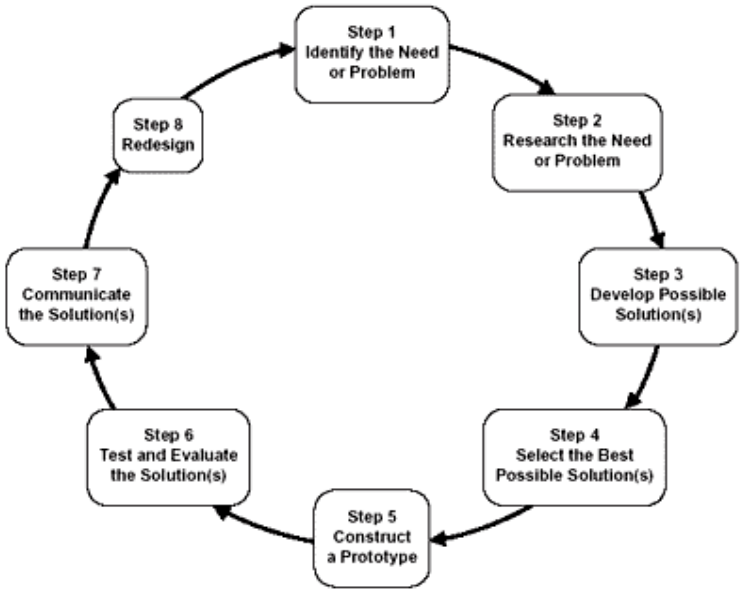

Figure 1: Steps of the Engineering Design Process[1]

Define the Problem. You and your team have been asked to design and build a model of a structure that is very robust and can withstand high structural loading. The specifications provided by the customer for your model are as follows:

> Each model must be at least 36 inches tall and support a weight equivalent to 10 pennies for at least 30 seconds. The winning prototype will have the maximum profit while adhering to the design constraints provided below.

Design Constraints:

- Height: Earn $100,000 for building a structure that is 36 inches tall. *Bonus:* $2,000 per inch above 36 inches.
- Strength: The structure must support 10 pennies at a height of at least 36 inches for at least 30 seconds without falling. After this, teams can load additional pennies onto their structure. *Bonus:* $500 for each additional penny loaded.

- Speed: The structure should be built within 25 minutes. Structures built in more than 25 minutes will be charged $2,000 for each additional minute. *Bonus:* $1,000 for each minute under 25.
- Material Costs: 3”x5” index cards are $1,000 each with a 100 card limit. Tape is $5,000 per roll. Scissors are $5,000 per pair.

Research. Evaluate online sources, textbooks, etc. for building structure ideas. Make sure you understand the limitations listed below.

- Teams will not be allowed to purchase additional cards or return cards once construction begins.
- Teams will be charged for the number of cards bought, not the number actually used, (i.e., no returns).
- If tape is used, it cannot be affixed to any other structure, (i.e., tables, chairs, floor, ceiling, etc.).
- The structure height will be determined by measuring the elevation of the highest card where loading will occur above the surface upon which the structure is built.
- If failure occurs during loading of additional pennies, teams forfeit the opportunity to earn a strength bonus. In other words, teams should know the capacity of their design prior to the day of competition.

Generate Ideas. In your planning session(s), develop a design plan and list of construction materials. Each team must decide how many cards they want to ‘buy’ and whether or not they will use tape and/or scissors.

Analyze and Compare. Using your knowledge of structures, along with any additional research you performed, determine the best solution to be built.

Build a Prototype. Each team will build a model in class using the specifications provided. Prior to this build, a typed design plan must be submitted at the beginning of the build. The design plan is evidence that you actually did ‘design’ and ‘planning’ for this activity, instead of just improvising on the day of the contest. The design plan will be graded for completeness, neatness, and accuracy to actual competition results, and should include:

1. Student names
2. Materials to be purchased
3. Expected structure height
4. Anticipated strength
5. Expected time required for construction
6. Calculations showing anticipated profit
7. Basic construction plan (describe how the structure will be built; who will do what)
8. Dimensional drawing of the structure that is to be built
9. Details documenting your team’s progress and activities during each phase of the engineering design process

Test your Design. Each team will test their model by attaching weights (pennies) to the top of the structure.

Communicate Results. Observations should be documented in the design report you will submit individually one week after testing. Sharing results with other engineers is how improvements in the information base, manufacturing techniques, and engineering technologies are made!

Redesign and Improve. An important part of your Conclusions section of your design report will be to discuss any improvements you would make if another round of testing were to occur. Ideally, the design process is a

cycle and should be repeated to improve efficiency and performance of your design. For sake of this class, we will go through the design process only once to give you a feel for the steps involved.

Project Timeline:

Class 1 (10/9 or 10/10): Project introduced and assigned.
Class 2 (10/16 or 10/17): Planning session. (Additional sessions will likely be required.)
Class 3 (10/28 or 10/29): Project build. Design plan due at beginning of class.
Class 4 (11/4 or 11/5): Project report due at the beginning of class.

Project Deliverables:

The structural modeling project has three deliverables:

1. Design Plan. Your team must submit a typed design plan detailed under Build a Prototype section.
2. Assembled Structure. Your team must build your structure and have it tested in the third project related class.
3. Design Report. Each group member must submit an individual design report one week after the testing of the structure model. The design report should be concise and informative. The report should include the major sections: ***Abstract, Introduction, Methods, Results, Conclusion***. This will be scored using the attached grading rubric.

1. "Technology/Engineering." *Science and Technology/Engineering Curriculum Framework*. Massachusetts Department of Elementary and Secondary Education, 1 May 2001.

Profit Calculation Worksheet

Costs

Cards purchased _____ x $1,000 each = _____

Rolls of tape used _____ x $5,000 each = _____

Pairs of scissors used _____ x $5,000 each = _____

Time used beyond 25 minutes _____ x $2,000 each = _____

Total Costs: _____

Revenue

Successfully built structure (Yes = $100,000, No = $0) = _____

Height – Additional height (inches above 36) _____ x $2,000 each = _____

Strength – Additional pennies (beyond 10) _____ x $500 each = _____

Speed – Available time not utilized (minutes under 25) _____ x $1,000 each = _____

Total Revenue: _____

Total Profit = Total Revenue – Total Costs = _____

Design Report Rubric – Structural Modeling Project

Abstract (10 pts)
Summarize the key point(s) from each section of the report. Be clear about the main objective and whether it has been met. Clarity and brevity are important. Note: The abstract is often the only thing the reader will examine to determine if your paper is worth reading!

Introduction (15 pts)
Begin the report in a natural way—assume the reader does not know the specific details of the background, relevance, objective, or approach. Be sure to establish relevance and the theoretical context of the method. State clearly the objective of the project and include relevant equations and theory when necessary.

- What is your objective?
- Why is this project relevant (context)?
- What background information or theory is necessary?

Methods (25 pts)
Describe how you went about designing your structure. What considerations and assumptions were important in the design? Include any analytical methods you used to compare competing design considerations. When necessary, give a description of which equations were used in your analysis and how important they were in coming to a conclusion. In addition, describe the test setup used to evaluate your structure in class.

- How did you go about designing your structure?
- What types of analysis did you use to compare different options?
- Did you use any important equations or relationships?
- How was the structure loaded? Why is this loading important?

Results (25 pts)
Describe your final design and any iterations that occurred as you performed your analysis. Explain how the results of your analysis support your design choices. Include appropriate plots and tables with your actual numerical results, and be sure to include captions, keys, axes labels, and units. Describe why relationships are important if you use specific plots as a means of analysis. Also give the results of the structural test.

- What does the final design look like?
- Have you clearly stated the results of your analysis?
- Have you fully described and justified your design choices? What assumptions, if any, were made?
- How did it perform?

Conclusions/Discussion (25 pts)
Begin with a clear overall summary of the objective, approach, and result. Identify any potential shortcomings of the build, if any, and explain what extent these might affect the result and conclusion. Be specific and realistic. If appropriate, identify how the build might be improved. Also, reflect on what you have learned from the project as a whole and how it might benefit you in the future.

- Have you clearly summarized the important main ideas of your analysis and design?
- What could be improved about your design or test?
- What did you learn? What was surprising?
- What engineering concepts have you applied (or will in the future)?
- What questions arose during the design process? What questions might you still have?