Project 3.1.5 Structural Efficiency

Introduction

Structural engineers face the challenge of designing structures that can support not only the weight of the structure itself but other loads as well, such as forces caused by people, furniture, snow, wind, and earthquakes. The structural framing system should be designed to carry these loads in an efficient manner. Because the cost of construction materials used to build a structural system is often based on the weight of the materials, it is cost effective to use the least amount of material necessary to provide a structure that can safely carry the applied loads. The most efficient structures are strong and lightweight.

One measure of the cost effectiveness of a structure is structural efficiency. Although structural efficiency can be defined in many ways, in this activity we will define structural efficiency rating as the ratio of the load applied to the structure to the weight of the structure itself.

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\text{Structural Efficiency Rating} = \frac{\text{Maximum Design Load Applied to Structure}}{\text{Weight of Structure}}
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It is important to understand that in this definition, the maximum design load applied to the structure is not necessarily the maximum load that the structure can carry. In order to provide an efficient design, the structural engineer must design the structure to carry the loads that are anticipated to occur, called the design load. So efficiency is based on maximum design load, not on the actual load that the structure can carry, which may be much higher than the design load. Of course, often the most efficient structure will be one that has a maximum capacity equal to the maximum design load.

In this project you will work in a team of three to design and construct an efficient structural frame (use playing cards and masking tape) to support a maximum design load of five pounds.

Equipment

- Engineering notebook
- Pencil
- Scale
- Twelve playing cards (per group)
- Masking tape
• Scissors
• Method of load application (Suggestion: a coffee can with a hole cut in the lid into which a pre-weighed quantity of sand or other objects can be inserted to slowly increase the load to five pounds).

Procedure

1. You will have just **20 minutes** to build a structure using the provided playing cards and masking tape that meets the following criteria.
   • 8 in. tall (± ½ in.)
   • Base dimensions not to exceed 4 in. x 4 in.
   • Top surface that can support the load application
   • The materials may be altered (cut, torn, folded, etc.)
2. Weight your structure.
3. You will have just **10 minutes** to test your structure. You will not have access to the official testing equipment, so devise a test method that will allow you to assess your design.
5. You will have just **20 minutes** to revise your design as needed to improve your efficiency rating.
6. Take a picture of your structure before testing.
7. Final competition -- as a class, perform official testing of each structure, tabulate the efficiency rating of each, and award the **Most Efficient Structure** award to the team with the highest Structural Efficiency Rating.
   
   NOTE: Any structure that does not meet the design criteria or that fails at a load of less than five pounds is disqualified from the competition.
8. Optional -- Predict the maximum load capacity of each successful structure, and then load each to failure. How does using the maximum load capacity of your structure in the calculation change the Structural Efficiency Rating?

Deliverables

Write a brief report on the structural performance of your structure. Include the following:
• Title Page
• Image of your structure
• Introduction to the project
• Competition Results
• Structural Efficiency Rating Calculation
• Conclusion including the results of preliminary testing, design revisions, and recommendations for additional structural changes to improve structural efficiency.
Conclusion
1. What factors could affect the choice of materials for the structural frame of a building?

   Three factors that would affect the choice of material for the frames would be cost, strength, and efficiency. Cost because the cheaper the cost the more likely you are to use it. The next one is strength, and this is obviously important because you want a material that is able to hold up a sufficient amount of weight and won’t cause a safety hazard. The final one is efficiency, which is how much the structure can way divided by the weight of the structure. This helps use your materials in a way where you save money and time.

2. Is it advisable to compare the Structural Efficiency Rating for two different proposed framing systems for a building if one system uses structural steel framing and the other uses cast-in-place concrete? Why or why not? If not, what would be a better comparison to determine efficiency?

   No it would not because these two materials are good for different structures. Steel would be better with a tall building so it can move with the wind while concrete is nice so shorter buildings intended to hold a big load. Two buildings made from the same materials and restrictions would make them more comparable.

3. Why would a structural engineer be more interested in the Structural Efficiency Rating using the maximum design load than the efficiency determined by using the maximum load capacity of the structure?

   It will show that it is strong enough to hold what it is intended to hold without including what else it could possible hold.