

The Effect of Bridge Design on Weight Bearing Capacity

Problem/Question

Which bridge material will have the greatest strength-to-weight ratio while utilizing one type of bridge structure (truss bridge): The Popsicle Stick Bridge or the Straw Bridge?

Research

The strength-to-weight ratio is the relationship between the strength and weight of a material. The strength-to-weight ratio is the weight that broke the material divided by the weight of the material. A truss bridge is constructed by making a grouping of triangles that are manufactured from straight and steel bars. The strengths of a truss bridge are it has a high strength-to-weight ratio and long lasting. The weaknesses of the truss bridge are it is usually expensive to construct and steel rusts eventually.

Hypothesis

I predict that if I compare the popsicle stick truss bridge and the straw truss bridge based on which bridge has the greatest strength-to-weight ratio, then the popsicle stick truss bridge would have the greater strength-to-weight ratio because a straw is lighter and less dense than a popsicle stick. The popsicle stick bridge would be more dense and have a higher strength-to-weight ratio.

Materials

- Popsicle sticks (about 60-100 per bridge, depending on the design)
 - Wire cutters, for cutting Popsicle sticks
 - Elmer's Carpenter's Wood Glue *or* Elmer's® Glue-All
 - Cotton swabs, for applying wood glue (about 100)
- Binder clips, in both medium and small sizes, for clamping joints on Popsicle stick bridges (12 of each size per bridge; you will need more if you build more than one bridge at a time)
- Plastic straws, straight (about 20-30 per bridge, depending on the design)
 - Clear tape, ½ inch width

Materials (continued)

- Gram balance for weighing bridges, such as the Fast Weigh MS-500-BLK Digital Pocket Scale, 500 by 0.1 available at [Amazon.com](https://www.amazon.com)
 - Masking tape
 - Loading block with hook or eyebolt, for testing bridge strength
 - Container for holding bridge load, such as a large bucket
 - Rope, $\frac{1}{4}$ inch to $\frac{1}{2}$ inch diameter (about 3 feet)
- Weights for testing bridge strength (can use metal weights, sand, or water in a container)
- Bathroom scale, for weighing how much weight it takes to break the bridge

Procedure

1. Gather the materials.
2. Download schematics for the [Warren truss Popsicle stick bridge \(pdf\)](#). Then construct the Popsicle Stick Bridge following the directions of the schematics.
3. Choose your popsicle sticks carefully by looking for straight, unbroken, knot-free sticks since weak popsicle sticks will make a weak bridge.
4. Pay careful attention to glue work at joints. Make sure you didn't use too much glue.
5. Construct the Straw Stick Bridge following the directions of the schematics but instead of glue and the popsicle sticks, used the $\frac{1}{2}$ tape and straw respectively. Make sure that the tape is not weak and ignored the part of the directions of the schematics that has anything to do with binder clips.
6. Take pictures of each of the model bridges.
7. Weigh each bridge before testing it so that you can calculate each bridge's strength-to-weight ratio after you break the bridge.

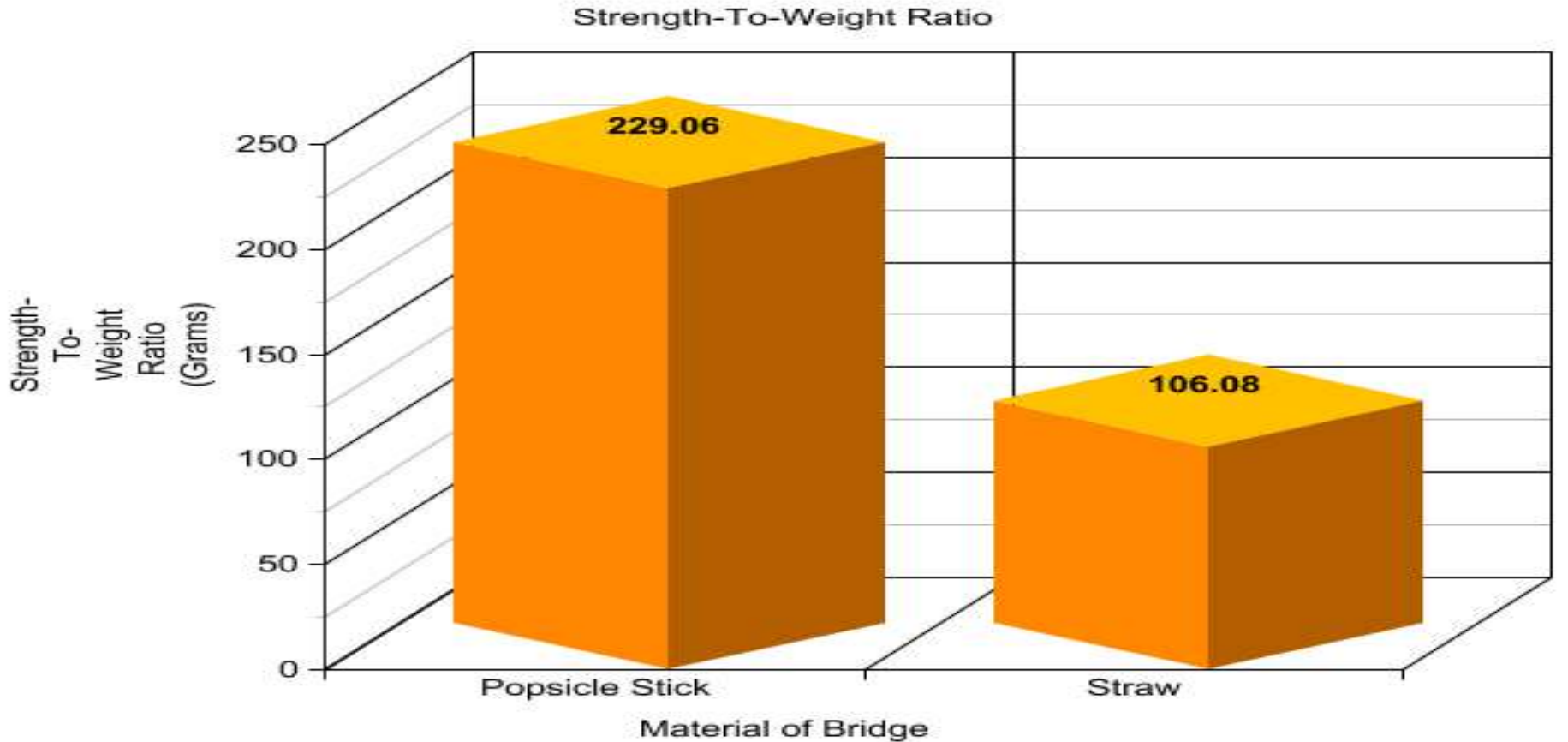
Procedure (continued)

8. Place the bridge to be tested between two chairs. The bridge needs to be high enough off the ground to hang a container with weights underneath it. It is best if the container is close to the ground so it does not have far to fall when the bridge collapses.
9. Place the loading block on the top, center of the bridge and tie a rope from the loading block to the container that was used to load the bridge. The bottom of the loading container should be 3 to 6 inches above the floor. If you have a video camera now is the time to start recording.
10. Gradually add weight (e.g., metal, sand, or water) to the container. If you want to use water, use water in capped bottles to avoid splashing when the bridge breaks.
11. Observe the bridge as you gradually added weight, and noted any changes that you observe. Then add weight until the bridge breaks.
12. When the bridge fails, weigh the container. Then record the weight that caused each bridge to collapse.
13. Take pictures of each of your collapsed bridges.
14. Calculate the strength-to-weight ratio of the bridge by dividing the weight it took to break the bridge by the weight of the bridge itself. Use the same units for the weight it took to break the bridge by the weight of the bridge itself.

Results

Material of the bridge.	Weight of the bridge (in grams)	Weight that collapsed bridge (in grams)	Strength-to-weight ratio (in grams)	Type of bridge
Popsicle Stick	100 grams	22906 grams	229.06 grams	Truss
Straw	24 grams	2546 grams	106.08 grams	Truss

Results(continued)



Conclusion

I observed that the popsicle stick truss bridge was heavier than the straw truss bridge by 76 grams. It took less weight for the straw bridge than the popsicle stick bridge to collapse. The difference was 20,360 grams. The way the two bridges collapsed were different. The popsicle stick bridge broke completely apart while the straw bridge looked wrinkled and some straws came off the tape. My hypothesis was proven correct because the popsicle stick bridge had a greater strength-to-weight ratio (229.06 g compared to 106.08 g).

The challenges of this experiment were getting the materials from the stores and making the straw bridge collapse since it was flexible, which explains why it and the popsicle stick bridge collapsed differently. I learned the definition of strength-to-weight ratio and how to calculate the strength-to-weight ratio. I also learned how a truss bridge is constructed from research and through the construction of the two model bridges I built. I also have an understanding of how material really makes a significant difference in bridge structure and even safety.

Resources

Science Buddies:

- http://www.sciencebuddies.org/science-fair-projects/project_ideas/CE_p011.shtml#summary/

Bright Huben Engineering:

- <http://www.brighthubengineering.com/structural-engineering/63635-truss-bridge-designs/>

PBWorks.com:

- <http://crebridgebuilding.pbworks.com/f/Isaac+Alex+Charlie+truss.doc>

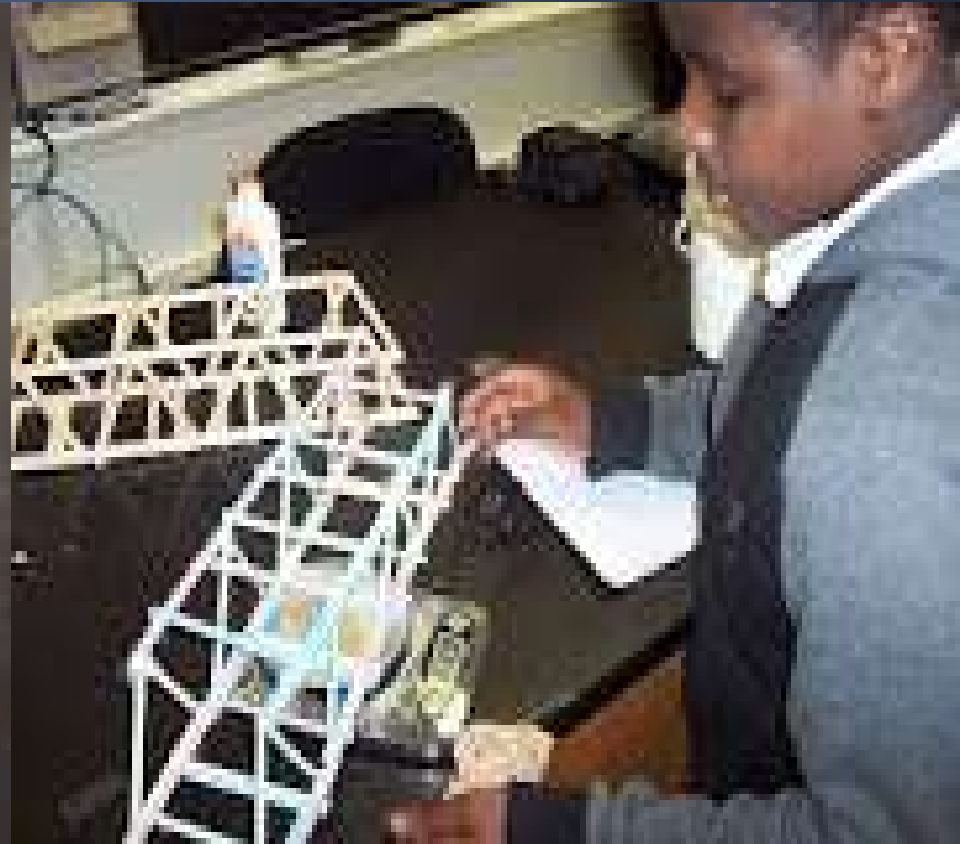
Toollingu:

- <http://www.toollingu.com/definition-500220-15916-strength-to-weight-ratio.html>

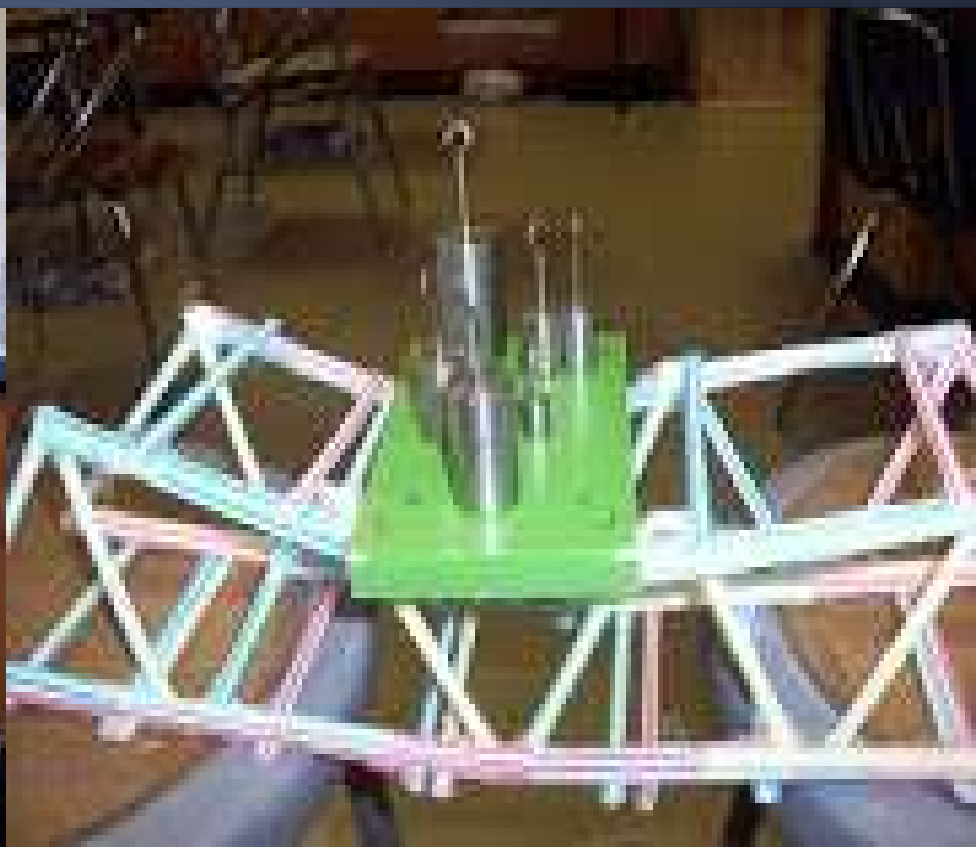
Pictures



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