Designing an Earthquake-Resistant Building

Your team has been asked by AusAid, an organization that manages projects for countries in need, to design a building that can withstand an earthquake in the Philippines. Acting like structural engineers, you will design, build, and test a structure that can withstand an earthquake simulated by a shaker table. Just as the earth has limited resources, so too do engineers. For this reason you must work within a budget. Remember to use the Engineering Design Model to help you.

You have these materials:

- 50 toothpicks ($0.30 each)
- 10 skewers ($1.00 each)
- 1 stick of plasticine ($1.00 per stick)
- scissors
- shaker table

Here is your problem challenge: Using the materials listed above, you are to design a building with the following constraints:

- The building must be at least two toothpick levels high.
- The building must contain at least one triangle.
- The building must contain at least one square.
- There must be evidence of cross-bracing to reinforce the structure.
- You may use whole toothpicks or skewers cut to size.
- You have a budget of $40.00 (maximum) to spend.

The group whose final design does not fall over when using the shaker table and remains in the exact shape it was before testing is the winner of the challenge. If more than one group achieves this, the highest or least expensive structure will win.

Directions for Making a Shaker Table

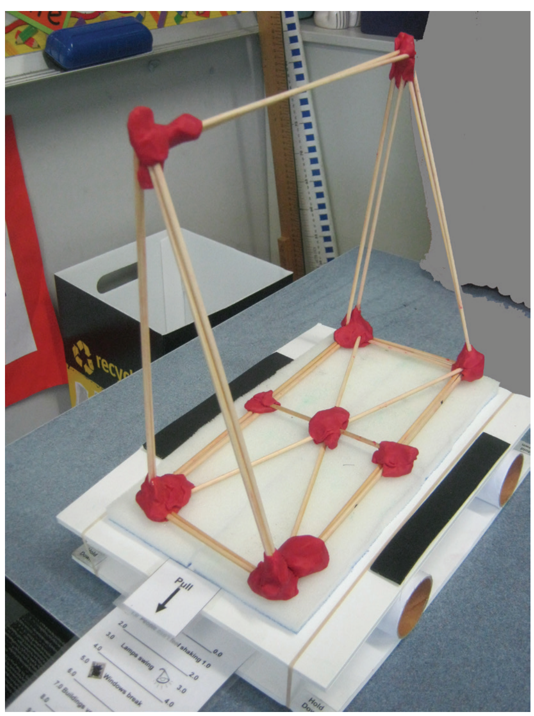
The shaker table is an adaptation of the engineering journal, downloaded freely from http://eie.org/sites/default/files/es_engineering_journal_2014_10_09.pdf (pp. 10–12).

Materials

- 1 magnitude meter (http://eie.org/sites/default/files/es_educator_guide_2014_10_09.pdf, pp. 21)
- masking tape
- 4 blocks of foam
- 16 hex nuts
- 2 rubber bands
- 2 plastic tubes
- 2 foam core boards

Instructions

1. Stretch rubber bands around both foam core boards so that they are close to the edges.
2. Put 8 hex nuts in a line on each side of the top foam board and secure them with a long piece of tape.
3. Make a pull tab by folding a piece of masking tape and taping it onto the center of the top board. Draw an arrow on it and write “pull.”
4. Stick the foam blocks onto the top board so that they cover the board but do not cover the rubber bands.



5. Place the two plastic tubes into the gap between the two boards.
6. Pull the tab; the top board should shake back and forth.
7. Line up the magnitude meter with the edge of the bottom board and tape the meter to the bottom board beneath the pull tab.
8. Ask a student to hold the bottom board while another person pulls the tab until the edge of the top board is over the magnitude of the earthquake that you require.
9. Let go; the table will shake back and forth.

Sample Dialogue from a Student Presentation on the "Designing an Earthquake-Resistant Building" problem

After completing the problem, each student group made a presentation to the whole class, explaining why and how students had refined their original designs to more effectively meet the problem goal. Below is an excerpt from one presentation.

Student 1: This is our second structure that we have made today. It was quite challenging, but it turned out the way we wanted it to. The other girls will explain why.

Student 2: We used cross-bracing in our design as well as tapered geometry. This made our structure rigid.

Student 3: We believe this is our best design because it was very stable and rigid and, umm, well, our first design, well, it wasn't as stable and rigid. And when we did the number eight on the Richter scale, it just fell apart a little bit. But this one [second design] didn't [fall apart]; it stayed right and survived the eight.

Student 4: The cost between the two [designs] were [sic] quite different. Our first one was $8.80, and we used sixteen toothpicks, three skewers, and one plasticine stick. And on our second one, we used five toothpicks, fourteen skewers, and two plasticines; and that cost us $17.50. And we thought that [*pause*], well, we got this design because, you know [*pause*], we were kind of just playing [i.e., experimenting], and . . .

Student 3: And we came up with the idea that if we had a square-base pyramid, umm, tapered geometry, umm, it would survive more because it was a rectangle [*pause*]. Oh, no; it was a triangle, and triangles are a strong shape.

Student 4: 'Cause our first one was literally this big [*indicating a rectangular prism approximately 15 cm high and 5 cm wide*], and it rocked around a lot [in testing]. So, we had to make it wider, but we weren't sure how we could. So, we were just playing, and we came up with our design.