Marshmallow and Toothpick Earthquake Activity

Activity Description

- Build a structure out of marshmallows and toothpicks and evaluate the effectiveness of multiple structural modifications in improving the building's resistance to a simulated earthquake.

Standards

Activity-Related

- Structure Modifications: observe the impact of increasing cross-sectional area on structural integrity.
- Joints: Construct an explanation of how joint stiffness affects structural integrity and understand why building joints cannot be too elastic or too stiff.
- Free Body Diagrams: Use free body diagrams to analyze the forces acting on a building pendulum counterweight during earthquake events.
- Extreme Weather Events: Understand the importance of structural integrity in ensuring human safety during natural disasters such as earthquakes.

Construction Sub-Activity

Materials

- 20 cm x 20 cm piece of cardboard
- 50 mini-marshmallows
- 130 regular-sized toothpicks (roughly 2.5 in / 6.25 cm)
- Metric ruler or yard stick with Metric markings

Directions

1. Build a structure that is 20-30 cm tall.
2. Make sure that your structure is securely fixed to the cardboard - this may be done by piercing the cardboard with the lowermost toothpicks in the structure
3. For this first sub-activity, do not modify the toothpicks or the marshmallows in any way (e.g. breaking them apart, etc.)
4. Make sure that each member of your structure only consists of one toothpick. If you do not end up using all the marshmallows or toothpicks, that is alright.
5. Proceed to the Earthquake Testing Sub-Activity.

Earthquake Testing Sub-Activity

Materials

- Stopwatch
- Wide and flat table surface
- Masking tape
- Ruler
- An assistant

Directions

1. On your flat surface, measure out a 60 cm track and place down small masking tape pieces to mark 0cm and every 20 cm. Make sure the tape will not interfere with your structure sliding along the track.
2. Start your stopwatch and begin sliding your structure back and forth along the track. Aim to complete one cycle of sliding per second.
3. With the help of your assistant, carefully observe the structure for any signs of collapse and qualitatively note the amount of swaying in the building.
4. If the building collapses within 20 seconds of sliding, note the time of collapse. Otherwise, record that the building survived the earthquake.

Joint Modification Sub-Activity

Materials

- Freezer
- Stopwatch
- A complete, unmodified set of materials from the Construction Sub-Activity

Directions

1. In this sub-activity, you will build the same structure but replace the soft marshmallows with hardened ones
    a. To harden the marshmallows, place them in the freezer for 1 hour beforehand. You may pursue other sub-activities during this time.
2. Recreate your original structure but with these hardened marshmallows. Make sure to work fast so that the marshmallows do not thaw too much.
3. Proceed to the Earthquake Sub-Activity.

Questions

- How did hardening the marshmallows affect the ability of the building to withstand earthquake forces? Was the amount of swaying affected?
- Under what situations or types of forces might an elastic joint be best for buildings? What about for a stiff joint?
    - Should building joints in general be completely elastic, completely stiff, or somewhere in between? Why?

Member Modification Sub-Activity

Materials

- A complete, unmodified set of materials from the Construction Sub-Activity

Directions

1. In this sub-activity, you will build the same structure but replace the single toothpicks with double-toothpicks (two toothpicks aligned side-by-side).
2. Proceed to the Earthquake Sub-Activity.

Questions

- Using double-toothpicks has effectively increased the cross-sectional area of each building member. Provide a broad description of why this should theoretically improve structural integrity in response to shaking forces.
- How did doubling the toothpicks affect the ability of the building to withstand earthquake forces?

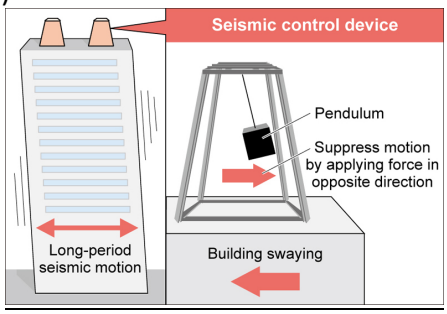
- How much longer did this building survive for? What was the ratio of this new survival time to the previous survival time?

Pendulum and Free-Body Diagram Sub-Activity

Materials

- A complete, unmodified set of materials from the Construction Sub-Activity
- Coin bag containing 5 quarters
- String (10 cm)

Directions

1. In this sub-activity, you will add a pendulum device to the top of your building and assess its ability to improve earthquake resistance.
2. Try to use the same amount of materials as from the Construction Sub-Activity. If your structure cannot hold the pendulum without collapsing, add more toothpicks and marshmallows as needed.
3. Make sure to leave space at the top of the building for the pendulum to swing (refer to the following picture).
   a. 

4. The hanging length of the string can be any length, as long as the pendulum can freely swing.
5. If your structure cannot accommodate the pendulum at the top, try moving the pendulum to the middle of the structure.
6. Proceed to the Earthquake Sub-Activity.

Questions

- For a given direction of sliding, in which direction does the building sway? What direction does the pendulum swing?
- Did the pendulum reduce swaying and/or improve the survival time of your structure?
  - If so, consider the forces acting on the building to provide an explanation for these phenomena.

Special thanks to Science Olympiad at Caltech & Southern California Science Olympiad for the development of this resource.