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Strain some Pasta!

Terremoto con pasta

A design challenge in which students use principles of engineering to build an earthquake resistant model structure out of pasta.

Recommended Grade Level: 6th -12th

NGSS Science & Engineering Practices: [6th to 12th]

- *Asking Questions & Defining Problems.* Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

- *Developing and Using Models*. Develop a model to generate data to test ideas about designed systems, including those representing inputs and outputs.

- *Planning and Carrying Out Investigations.* Collect data about the performance of a proposed object, tool, process or system under a range of conditions.

- *Analyzing and interpreting data*. Data collected in the tests of designs allows for the comparison of different solutions and determines how well each meets specific design criteria—that is, which design best solves the problem within given constraints.

- *Using Mathematics and Computational Thinking.* Use digital tools, mathematical concepts, and arguments to test and compare proposed solutions to an engineering design problem.

- *Designing Solutions.* Optimize performance of a design by prioritizing criteria, making tradeoffs, testing, revising, and re- testing.

Preparation:

Prep time for the instructor:

Shake table:

One time: Purchase supplies and assembly of the shake table – one hour (Information about this device can be found here.)

Structures:

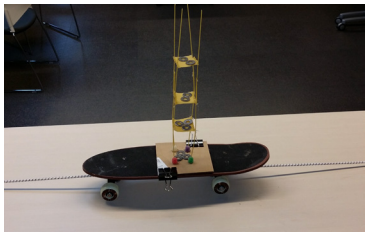
Purchase and organize materials for Earthquake structures – one hour

Instruction:

Introduction and background information for student pre-challenge.

Depending on detail – multiple hours

Project time:



Timeline for student groups:

- Student timeframe depends on several factors:
  - Grade level
  - Academic level
  - Previous collaborative experience

  In-class vs. out-of-class time available for this project
- In general (once instruction and background information has been given):
  - Initial design – 1 to 2 hours
  - Initial building – 1 to 4 hours (depending on glues used)
  - Testing – 1 to 2 hours
  - Reengineering next versions – multiple hours

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Materials Needed (for each group working in challenge teams)

- A piece of Cardboard: 15cm x 15cm (this size can be adjusted depending on the size and width of the shake table skateboard)
- 12 pieces of full length spaghetti
- 1.5 pieces of lasagna noodle
- Glue -7 grams total (5 grams for structure and 2 grams for washers – see "Design constraints below" for more details)
- either:
  - White/construction glue
    Or
  - Cold / Hot melt glues which require
    - Glue guns
    - Glue sticks

Note: If safety is a concern, consider using low melt temperature glues and guns. However, hot melt glues are stronger and easier to work with.

- 4 gumdrops
- 10 x 3/8 inch flat washers (Coins, suck as nickels or quarters can be used as a substitution)
- A metric Ruler
- Mass balance
- Goggles
- A Shake table - Materials for the construction of the shake table using a skateboard can be found here.

Background Information

Earthquakes generate seismic waves. Buildings are susceptible to failure if the ground shaking weakens their structural integrity. Huge numbers of people are killed every year by building collapse due to earthquakes – this is a "real world problem" (ETS1-2). (Approximately a quarter million people died because of building failure in the 2010 Haiti earthquake alone.)

In this Earthquake Engineering challenge students will model how an earthquake affects buildings. By adhering to various design constraints, each team will build a model structure made out of **pasta.** Each team will use a shake table to model the vibrations caused by an earthquake (see "What to do" for the design of shake table). The challenge will be to see how each structure responds to these simulated waves…will it survive; suffer a few cracks or be a complete disaster?

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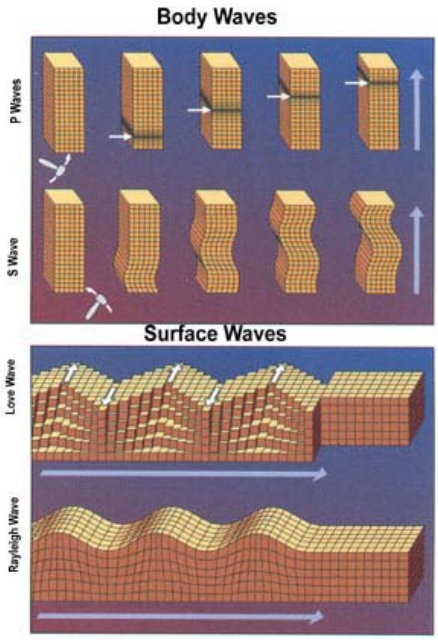
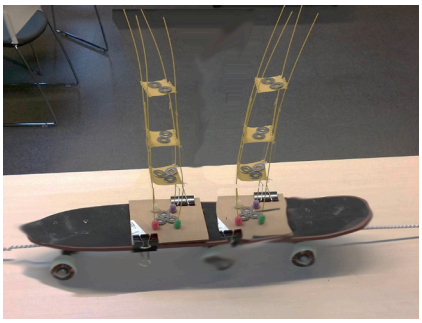
Below are a few concepts that are integral and can be integrated into this activity:



- *Seismology:*
  When an earthquake occurs, four major types of seismic waves are created: P-waves, S-waves, Rayleigh waves and Love waves. These four waves can be separated into two main categories: Body waves and Surface waves. Body and surface waves have different speeds, waveforms and effect structures differently. The waves generated by the shake table in this activity (click here to see shake table design) most closely resemble a surface wave or more specifically, a horizontally polarized surface wave or Love wave. Plan your building design with this in mind.

- *Frequency, amplification and resonance:*
  When an earthquake occurs, the ground and structures built upon that ground vibrate. These vibrations can be measured in frequency (or shakes per unit time). Resonance occurs when a specific frequency (or multiple of frequencies) causes an amplification or greater amount of vibration.

  When designing a building, you do not want your building to be in resonance with an earthquake. Determining the frequency of the shake table before your simulation or finding your model's resonant frequency might aid in its stability and survival.
  Resonance should play a factor in your building design. (ETS1B - Developing Possible Solutions)
  - Which would be better, constructing a low structure or tall structure?
  - Should you build a rigid or flexible structure?
  - Should you build the structure wide or narrow?
  - Where and how should you attach your pasta?



- *Acceleration:*
  Buildings are structures that are set firmly in the ground and aren't supposed to move. However, earthquakes can move things very rapidly from a stand still. Acceleration is the change in speed of an object. Will your structure be able handle going from being stopped to moving in one direction then another direction very rapidly? Determining the acceleration of the shake table might help in this challenge?
  Acceleration should play a factor in your building design. (ETS1B - Developing Possible Solutions)
  - Should you reinforce areas of your structure (especially the lowest floors like shear walling)?
  - How fast can your pasta structure bend?
  - How much can your pasta structure bend?

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- *Structural engineering:*
  Because earthquakes send huge forces through a building, Engineers incorporate a variety of design features into their structure. These design techniques may help your building withstand damage and collapse. Structural design should play a factor in your building. (ETS1B - Developing Possible Solutions)
  - Do research: Look at other buildings and see how they are constructed.
  - How should you connect your pasta (structural members)?
  - What geometries should you use?
  - Would making connections meet at right angles or other angles be better?
  - Would cross-bracing help?
  - Should the pieces of pasta be long or short
  - What should be the size of your base? Narrow or wide?
  - How much of your limited glue should you use and where?
  - Which pieces of pasta will be in compression and which will be under tension? Will this change how you arrange your pasta?

- *This is a challenge:*
  Do you want to merely survive the challenge or win it? Should you push the limits of the design constraints? Do you want to take risks with your design (be innovative) or be more conservative in your design? You will "win" more points in this challenge if you approach the structure's limits. (ETS1C - Optimizing the Design Solutions)
  - What shape and look do you want for your structure?
  - Your design does not have to be symmetric. It can be structurally different at different heights.
  - Do you want to test it before the final challenge?
  - Should you make a redesign?

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What To Do:

- *Review the differences between science and engineering.* In particular, while scientists start by defining a question to solve (Why do earthquakes happen? How and when might they happen again? Can it happen here?), engineers start by defining a problem to solve (Can we build a structure that will safely and effectively survive an earthquake?) In this engineering challenge, *the problem is to build a model structure out of pasta that will resist the shaking of a simulated earthquake.*

- *Build the shake table:* *Shake it up! - Make a Shake Table*. The shake table is a necessary platform to perform this challenge. The material list and design instructions for this device are located on a separate document and can be accessed by clicking here.

- *Build the Structure. Make a structure of pasta to test for earthquake resistance*. Below you will find the engineering/design constraints as well as some planning and assembly pointers. Read and follow these carefully to help your team meet the 4 basic engineering goals of any project:

    - *Was your project on time*?
    - *Was your project within budget*?
    - *Does your project meet specifications?*
    - *Does it work?*

A. Design constraints (ETS1.A: Defining and Delimiting Engineering Problems):

1. Your project must be completed by the assigned due date.
2. The structure can only be built with the materials listed above in the section titled "Materials needed."
3. You may use only 7 grams of glue.
    a) It is recommended that **5** grams are used for the structure and **2** grams are used to secure the washers to the structure. The function of washers and how to attach them will be made clear later in section 10 located below.
    b) To ensure the weight of the glue:
        1. Before building your structure, weigh the following allotted materials and record the mass directly on the cardboard:
            a. Spaghetti (12pcs),
            b. Lasagna (1.5pcs)
            c. Gumdrops (4pcs),
            d. Cardboard base
            e. 10 washers.
        2. After the structure is built, re-weigh your completed structure before the final testing. This mass is to be recorded on the cardboard too.
        3. The difference, due to the use of glue, can't be more than **7** grams! Write this difference on the cardboard!
4. The structure can only be built on the cardboard base. This base represents your "property" which you can build upon.
5. The structure can only be as big as the cardboard base…nothing hanging over the edge of the cardboard.

6. Except for the cardboard base, each successive floor must be made of lasagna, but the lasagna can be used for more than just flooring. (The cardboard base is considered the bottom or 1st floor).
7. Each floor must be separated from the other floors by a minimum of 10 cm. Only floors separated by at least 10 cm of clearance will be counted for points.

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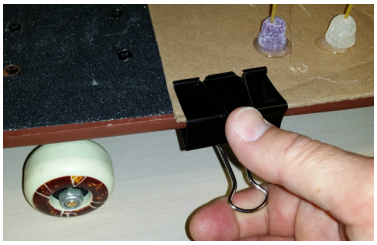
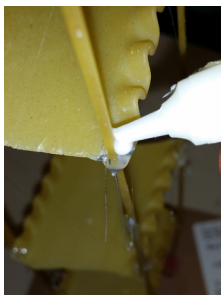
8. Only 4 gumdrops can be used in your structure.
    a) Gumdrops works well as your foundation (to hold the spaghetti on to the base).
    b) Gumdrops do not have to be used "whole."
9. You must allow room for clamps or clips. These are to be used to attach the base to the shake table.
10. Add Washer to your structure. Washers can be thought of as occupants or rent paying tenants and will help add to your team's point total.
    a) There is a limit of 10 washers
    b) Washers can not overlap
    c) A washers must be all on a floor (no bits hanging over the edge).
    d) Washers on higher floors count for more points (higher rent)
    e) Washers must be glued down,
    f) Washers should not need more than 2 grams of glue out of the 7 total grams allotted glue.



B. Planning and assembly:

- There are no set plans for your structure.
- Plan and work on this project cooperatively with your team.
- Get some extra pasta and:
    - Practice breaking it to size
    - Practice joining pieces with glue
- Your pasta structure will break very easily: be careful and take your time.
- When gluing:
    - Use caution and goggles when using glue guns.
    - Support each piece while gluing.
    - Allow time for the glue to set/dry.
    - You might need an extra hand or a jig to keep your pieces in place.
- Washers (renters in your structure): Washers have mass and will affect your structure's ability to handle an earthquake (shake table).
    - Keep their arrangement in mind when designing your structure.
    - Place your washers in the desired orientation and glue them down.
    - You only need a dab of glue to hold them down.



· Good luck!

- *The Rumble - Pasta structure and shake table design challenge and scoring*. This is a separate handout. This handout contains an overview for the final testing of each team's structure. Click here to access this document.

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What's Going On?

Structural engineers try to minimize the damage an earthquake can cause to a community. These engineers help improve existing structures and make new and better buildings. Since using "full-size" structures is difficult and expensive, engineers often use models to simulate how various designs will perform. Engineers conduct systematic tests, collect and analyze data, make trade-offs and redesign systems and mechanisms based on continually updated information. Testing models help engineers meet their design goals and work within their given constraints.

Going Further (optional)

This is an introductory lesson for earthquake engineering. Many parameters of this challenge can be changed to fit the needs of a particular class or topic (altering the design constraints or engineering goals). Small changes in design might make a huge impact on your structure's survivability.

Possible permutations:

- Change the amount of material used.
- Change the types of materials (use other kinds of pasta, cardboard, popsicle sticks…etc.).
- Try other types of glues (epoxies, putties or marshmallows).
- Figure out which pieces are under compression or tension and choose building materials accordingly (i.e. switch out pasta for string in sections under tension).

Go beyond a hands on classroom activity:

- Include a trip to an actual building to see its seismic safety features.
- Cover current events about natural disasters
- Discuss social issues related to structural failures.

Technology options:
You can analyze your structure by using slow motion video. Many cameras and mobile devices allow for such image capture. The information you get from this might help steer your design or redesigns.

Recommended Web Sites (optional)

- IRIS and videos by John Lahr
- Seismic wave activities with slinkies
- Resonant rings
- Resonator
  Don Rathjen's Shake table design
- The USGS is a great source of information on earthquakes and seismology.
  - For Educators
    For Kids
- The Association of Bay Area Governments
- Teach Engineering
  Pacific Earthquake Engineering Research Center
- Building safer building
- Frequency and buildings
- Images above:
  - Collapsed building
  - Transamerica tower