SCIENCE NORTH SCIENCE NORD
SUDBURY, ONTARIO, CANADA

Earthquakes Part 4 **Grade 5 – Forces Acting on Structures and Mechanisms**

Lesson Plan

Assessment	AFL, earthquake simulation
Cross-curricular	

Big Ideas

- Structures and mechanisms throughout our environment have forces that act on and within them.
- We can measure forces in order to determine how they affect structures and mechanisms. This information can be used to guide the design of new structures and mechanisms.
- Forces that result from natural phenomena have an effect on society and the environment.

Learning Goals

- To come up with ways to reinforce a building against earthquakes through inquiry based experiments.
- To understand the interplay of forces in a structure under external stress.

Specific Expectations:

1.1 analyse the effects of forces from natural phenomena (e.g. earthquakes) on the natural and built environment
2.1 follow established safety procedures for working with tools and materials
2.3 use scientific inquiry/research skills to investigate how structures are built to withstand forces
2.4 use technological problem-solving skills to design, build, and test a frame structure that will withstand the application of an external force or a mechanical system that performs a specific function
3.4 describe forces resulting from natural phenomena that can have severe consequences for structures in the environment, and identify structural features that help overcome some of these forces

Description:

This is the **fourth** out of five lessons on the forces of structures in an earthquake. In this lesson students will build on what they learned in lesson three by reinforcing and/or modifying the design of their structures.

Materials/Resources:

Cardboard pieces (about 5cm x 5cm)
Masking tape, Straws
Toy cars (1 or 2 per group)
A weight – small container filled with water
Marble or ball bearing and string – to make a counterweight pendulum
Slide show Visuals

Safety Notes

Introduction

Review and Introduction to today's activity

- What did you learn yesterday? Here are some expected outcomes:
    - Taller structures are more affected by earthquakes – a small shift at the bottom creates more torque on the building allowing it fall over more easily.
    - When blocks touch each other less they slide apart more easily. This is because the friction between them is lower, leading to lower structural strength or ability to withstand tension within the building.
    - Larger oscillations – larger earthquakes, destroy structures more completely.
    - The orientation of a building in an earthquake can have a big impact on how it is affected. For example a long building that is aligned with the direction of travel of the oscillations (shaking) of the earthquake will do much better than one that is perpendicular.
    - The wider the base of the structure the more stable it is.
- Engineers constantly come up with ways to make structures stronger and more capable of resisting large forces applied to them. This doesn't just include earthquakes but also such things as wind, fire, flooding, etc.
- Today you are going to look at your structures through the eyes of an engineer.
    - How can you make your structures stronger?
    - How can you make them more resistant to earthquakes?

Action

We'll start with some free exploration, letting the students come up with their own ideas on how to make their buildings earthquake proof. After that we can guide them through some of the possible modifications if they didn't experiment with them yet. Our suggestion is to let them play until some cool concepts have emerged. Then, bring them together, and have the groups who came up with something interesting display it. Time permitting, you can then let them try some more things or instruct them on something to try (such as putting the building on wheels).

Improving Structures and Testing Them

- Yesterday you experimented with different building designs. Today we want to focus on modifications to any building design that will make it stronger. So take a building design that was really easily destroyed by an earthquake and see if you can make it stable.
- We won't tell you how, but here are some supplies you can use:
    - One cardboard piece per group (maybe 5cm x 5cm), meant to be used as a platform to tape to toy cars (see image), but you don't need to tell them that. Have extras in case they decide to cut them up and need another piece for their platform later).
    - 1 metre of masking tape (or less if you want to make it more challenging).
    - One or two toy cars - low flat ones, such as dump trucks, work well.
    - Several straws
    - A weight (e.g. a small Tupperware filled with water)
- Give students time to explore solutions. Try several things!
    - Be mindful of the limited supplies – engineers have to keep down cost as well as meet all their construction challenges!

Demonstration and Discussion

- Let students show their best modifications
- Why did these modifications work well?
    - **Eliminates shear** between blocks (e.g. with straws). Shear is a form of internal tension in the structure.
    - Force of earthquake **not transferred** to structure (e.g. using a rolling platform)
    - Change the **equilibrium** of structure – reducing torque (e.g. by placing a larger weight at the bottom)
    - **Increased compression** between blocks (e.g. by having more weight at the top – but it may also increase torque, resulting in a building that won't crumble but may topple over as one whole structure)
- If students didn't yet try to place the structure on a rolling platform have them do that. Detaching buildings from the surrounding ground is a commonly used technique. Though we wouldn't use wheels in the real world but something called isolation bearings, which work in a very similar fashion.
    - Show some images of isolation bearings (a simple image search will turn up all kinds of neat designs. See slide show for a few neat examples.
    - Video showing a test very similar to what the students are doing. Show after they do their experiment! https://www.youtube.com/watch?v=kzVvd4Dk6sw

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Consolidation/Extension

Damper Pendulum (can be done by students or a teacher demo if time is short)

- As a great extension have the students build a damper pendulum (called a tuned damper pendulum), similar, for example, to the one inside the Taipei 101 tower (see slide show).
    - Attach string to a marble or ball bearing using masking tape
    - Hang the marble inside the top of your tower (see image below).
    - Make an earthquake and observe how the pendulum starts swinging, creating a counter balance to the motion of the swaying structure.
        - This experiment will work best if the tower is re-enforced with straws (so it sways as a whole) and is NOT attached to the poster paper so it can topple.
        - You should notice a very clear difference between the towers stability when the pendulum is in vs. when it's out. If you make it possible to just slide the pendulum in and out you can go back and forth between the two setups.
        - As the building sways one way, the pendulum sways the other way, creating a balance. What really happens is that the building sways while the pendulum actually stays in place.
        - The heavier the pendulum the better it will be able to compensate for large swaying of the building.
        - The higher from the ground the pendulum hangs, the better it will work. This is because just a small amount of swaying creates a large torque on the building. You can test this by hanging the pendulum far down in your tower and see if it still managed to stabilize it.

Unit Project:
There may not be much time to work on this. We will have lots of time in lesson 5 to finish the project.

- Describe the experiments and outcomes undertaken today. Use the attached worksheet template if desired.