Skyscraper Science

Grade Level: 4-8

Lesson Overview

Students will learn about various science concepts used in the building of skyscrapers and put these concepts into the building of their own skyscraper.

Student Objectives

1. Construct of a model skyscraper using gained knowledge.
2. Demonstrate compression and tension of building materials.
3. Use forces of gravity and load in a positive manner in their building.
4. Demonstrate ways to strengthen building materials.
5. Exhibit tension, compression, and torsion qualities in different materials.

Materials

- ✓ Student Worksheets
  - Testing Materials
  - Working with Columns
  - Tower Building
  - Straw Shapes
  - Build a Skyscraper
- ✓ salt (Must be saved after use)
- ✓ funnel
- ✓ samples of 6 different materials: string, popsicle sticks, pipe cleaners, rubber bands, drinking straws,
- ✓ box of drinking straws (7 per student pair)
- ✓ box of regular sized paper clips (14 per student pair)
- ✓ empty toilet paper tubes (at least 2 per student pair)
- ✓ box lid or such to catch any spilled salt or sand
- ✓ masking tape
- ✓ 2 sheets of newspaper per student pair
- ✓ ruler
- ✓ samples of 6 different materials, i.e. clay, strips of kitchen sponges, paper towel tubes, pencils, erasers, aluminum foil, ceramic tiles or strips of cloth
- ✓ rope
- ✓ golf balls

Vocabulary

- **buckle** – to fold or collapse under compression.
- **column** – a vertical, structural element, strong in compression.
- **compression** – a pressing force that squeezes a material together.
- **core** – central portion of skyscraper; usually houses elevator and stairwell.
- **dead load** – weight of a structure itself.
- **force** – any action that tends to maintain or alter the position of a structure.
- **foundation** – base on which a building stands.
- **gravity** – pull towards the center of the earth.
- **load** – weight distribution throughout a structure.
- **stable** – ability to resist collapse and deformation.
- **tension** – a stretching force that pulls on a material.
- **torsion –** an action that twists a material.

Background Information

The use of skyscrapers became important in large cities as land became more and more expensive and scarce. Vertical space became the norm. More information is found in the lesson Stockyards to Skyscrapers.

Procedure

Note: As students complete student worksheets, you may want them to write their predictions in pen.

1. Activity one: Students will rate different materials on their tension, compression, and torsion. The teacher can use a rope to demonstrate the three tests. Have two kids tug on the ends of a rope (tension), then push the ends together (compression), and finally twist the ends of the rope (torsion). With each test, have the group suggest a rating using the scale on the worksheet. (The rope is strong in tension, but weak in compression and torsion.) Have students complete Testing Materials student worksheet.

2. Activity two: Students will learn how to strengthen a column for construction. Teacher will hold up a toilet paper tube and ask the students if they think she/he can stand on it. Challenge the students to think of ways to make the tube strong enough to hold your weight. Let students experiment. Note: by adding sand or

salt to the tube, it gains strength. Have students complete Working with Columns student worksheet.

3. Activity three: Students will learn that a building material can be altered to provide strength. Have students complete Tower Building student worksheet.

4. Activity four: Students will experiment with squares & triangles to create strength and stability. Have students complete Straw Shapes student worksheet.

5. Activity five: Students will build a skyscraper using the information they have learned. Have students complete Build a Skyscraper student worksheet.

Extension Activities

1. Students may take photos or make drawings of buildings in their town that show cross bracing, triangular shapes, and other information that they have learned in this activity.

2. This lesson correlates to Stockyards to Skyscrapers.

Additional Resources

- http://www.pbs.org/wgbh/buildingbig/skyscraper/index.html - activities for students and teachers
- http://www.greatbuildings.com/types/types/skyscraper.html - list of worldwide skyscrapers and information concerning them.

Standards

Illinois Science Standard

MS.PS2.2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Illinois English Language Arts Standard

ELA.RST.1. Cite specific textual evidence to support analysis of science and technical texts.

The **M**ultidisciplinary **AG**ricultural **I**ntegrated **C**urriculum (mAGic) was created in 2004 under the leadership of the Illinois State Board of Education (ISBE) and the Facilitating Coordination in Agricultural Education Project (FCAE). Funding was made available through the FCAE grant budget from the agricultural education line item of the ISBE budget. This revision, as printed, was developed in January 2021.

These mAGic lessons are designed to bring agriculture to life in your classroom. They address the Illinois Learning Standards in math, science, English language arts and social studies.

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Name _____

Testing Materials

Materials needed: 3 samples each of at least 5 different materials, such as yarn, popsicle sticks, pipe cleaners, clay, sponges, erasers, rubber bands, paper towel tubes, pencils, cardboard, aluminum foil, drinking straws, tiles, or cloth.

Directions: **Predict** which materials will be strongest in tension, compression and torsion. Write your prediction on the chart below **BEFORE** you actually test the materials. (Tension is pulling on the material from both ends, compression is pushing the material together from both ends, and torsion is to twist the two ends in different directions.)

Rating Scale:

1 Very weak. It crumples or breaks with hardly any force.
2 Only fair. It can't withstand much force.
3 Pretty good. It takes a lot of force to break.
4 Super strong. It doesn't break.

Test the materials.
Tension: Pull on the material from both ends. Record your rating on chart.
Compression: Push the material together from both ends. Record your ratings on the chart.
Torsion: Twist the two ends in different directions. Record your ratings on the chart

Material	Predicted Tension Rating	Actual Tension Rating	Predicted Compression Rating	Actual Compression Rating	Predicted Torsion Rating	Actual Torsion Rating

Answer the following questions:

1. Which materials were strongest in tension?
2. Which were strongest in compression?
3. Which were strongest in torsion?
4. How did you do with your predictions?
5. Which material surprised you the most?
6. Which materials were the strongest in all three categories?
7. Consider the shape of the material. Choose a material and design a test that would show you if shape mattered in each of the tests.

Name _____

Working with Columns

Materials needed: 2 empty toilet-paper tubes, sand or salt, dishpan, tray or cardboard box lid, masking tape, sturdy chair, and a funnel.

Directions: **Predict** whether or not the paper tube can withstand your standing on it **before you actually stand on the tube.** Explain the reasons for your prediction.

Rating Scale:

1. Very weak. It crumples or breaks with hardly any force.
2. Fair. It can't stand much force.
3. Good. It takes a lot of force to break it.
4. Very Strong. We can't break it.

Test the tube.

1. Place an empty box lid on the floor. Stand the empty tube (the column) on one end in the lid.
2. While holding on to the back of the chair with both hands, gradually press straight down on the top of the column with one foot. Continue increasing your weight on the column until it collapses. Rate the column according to the scale above on the chart below.
3. Observe the collapsed tube to see where it failed. Brainstorm as to how you can make the column stronger by only using tape and sand. Once you have decided how you can strengthen the column, make it with your second toilet-paper tube. Answer the following questions.

Column Used	Prediction Rating	Observations
Empty Paper Tube		
New Design		
Further Testing - if you wish		

1. How did your strength ratings for the two columns compare?
2. What do you think made the differences?
3. Did any part of the test surprise you?
4. If you were building a tall building, what would you have learned about the columns to be used from this experiment?
5. Write a summary of what you learned from this experiment.

Name _____

Tower Building

Materials needed: 2 unfolded sheets of newspaper and a ruler per group of two.

Directions: **Predict** how tall a tower you can build using the newspapers. What makes you think that? Write your predicted height on the chart below.

Test your prediction.

1. Build your tower. If you think you can make it taller, try again - keep working on it until you can't make it any higher.
2. Measure the height of your tower and record it on the chart.
3. Ask your teacher for 8 inches of tape. Using the tape, can you make your tower taller? (You cannot tape the tower to the table; the tape has to be used as a part of the tower.)
4. How tall can you build the tower and have it support the weight of 2 long pencils? Measure and record your results on the chart.
5. Now see how well your tower can withstand wind (fan it with paper) and an earthquake (shake the table). Record that information on your table.
6. Brainstorm different things you could do to make your tower stronger so it could stand up to the forces of nature. List your ideas:

Predicted height of the tower made with newspaper	Height of tower made with just the newspaper	Height with using tape	Height that withstood weight of 2 pencils	Did it withstand the force of wind?	Did it withstand the force of an earthquake?

Name _____

Straw Shapes

Materials needed: 7 drinking straws and 14 paper clips.

Directions: **Predict** which shape will be more stable. Circle One:
Square: Yes No Triangle: Yes No Why do you think this is true?

Test the shapes.

1. With your partner make your shapes by pushing a paper clip inside one end of a straw. Link another clip to the first and push the second clip into the end of a second straw. Continue until you have constructed a triangle and a square.
2. Compare the stability of the shapes. Hold each shape upright and press down on the top corner.

   What happens?

   How much does each one bend and twist?

   Square:
   Triangle:

   How hard can you press down before it collapses?

   Square:
   Triangle:

3. Can you make the less stable shape stronger by adding no more than 2 straws and 4 paper clips?

   Draw your new design and explain why you feel this is stronger.

Name _____

Build a Skyscraper

Materials needed: Drinking straws, paper clips, newspaper, tape, 4 toilet-paper tubes, golf balls and salt or sand.

Directions:

1. After completing the previous four activities, use the information you have learned to build your skyscraper. Your challenge is to build the tallest skyscraper you can that supports the load of a golf ball, using only the materials given.
2. After making your skyscraper, draw a diagram of it. Be sure to label the parts of the skyscraper that show what you have learned about columns, shapes, and height.
3. Write a summary of what you have learned in these activities. You may look back at the worksheets to help in your writing. Be sure to explain how you have increased the strength of your skyscraper.

Worksheets 1-5 ANSWER KEYS

Worksheet 1: Testing Materials Different materials have varying abilities to withstand compression, tension and torsion. Results may vary somewhat, but generally the students will learn the following:

- Strong in tension: string, yarn, pipe cleaner, popsicle stick, ceramic tile, cardboard, drinking straw, cloth, rubber band (strong but very flexible), rubber eraser, paper-towel tubes and pencil.
- Strong in compression: popsicle stick, clay (limited), ceramic tile, rubber eraser, paper-towel tubes (limited) and pencil.
- Strong in torsion: ceramic tile, rubber eraser (limited), paper-towel tubes, and pencil.

Worksheet 2: Working with Columns Students will find different solutions to increase the strength of the tube. Reinforcing the sides of the tube by wrapping it with tape makes it a bit stronger. (The tape increases the stiffness of the sides of the tube and helps it resist buckling.) Placing tape over the ends of the tube and filling it with sand or salt increases its strength enough to hold a person's weight. (The sand's tendency to spread out is resisted by the sides of the tube, which hold it and enable it to support the load.)

Worksheet 3: Tower Building Pleating or rolling paper can increase the stiffness. By crumpling, folding and otherwise reshaping the flat sheets and forming a base, the newspaper can be made to stand up. (Gravity and the dead load of the tower push down, the ground pushed back up, and small air movements push from the side. The foundation distributes the load into the surrounding ground material and helps balance the sideways wind force. The size of the foundation depends on the strength of the supporting ground. A foundation placed in rock can be smaller than a foundation placed in sand or mud.) Students may use the tape to stiffen the newspaper, especially at the base, or to hold stable shapes like triangles or columns together. (Dead load is the weight of the tower itself and live load is the weight of the crayons.)

Worksheet 4: Straw Shapes Straws arranged into triangles are more stable than straws made into squares. When compression force is applied to the joints, a triangle changes shape less than a square. When compression is applied to a square, the joints rotate easily, and the shape changes. In a triangle, the compression in the two sides is balanced by the tension in the cross-piece at the bottom, which pulls the sides back together. This balancing of forces results in a more stable structural form. The students should make a triangle within the square to make the square stronger with only two straws and four paperclips.

Worksheet 5: Build A Skyscraper Students should build a skyscraper that will exhibit the concepts they learned in the preceding activities. This activity may be used as your lesson evaluation.