week 6

Scrapers in the Sky

Build the tallest freestanding skyscraper that will hold the most weight.

Subjects and Skills

- Adaptation of materials and design elements
- The impact of nature on design
- The history of skyscrapers

Materials

- Newspaper
- Two pieces of 9"x 12" construction paper per team
- Tape
- Golf balls, pennies, or other weight

Vocabulary

- Skyscraper
- Industrial Revolution

Purpose

The principles behind skyscrapers link civil engineering concepts with science and history. When we study the fundamentals of skyscrapers, we are better able to understand the history of urban progress and development, and we can improve the way we plan cities in the future.

Objectives

Students will gain a better understanding of:

- the history of skyscrapers and the basic design principles behind their success;
- the forces that affect tall structures;
- the different structural engineering principles relating to skyscrapers; and
- the challenges faced by engineers in building tall structures.

Activity Preparation

1. Run off activity sheets.
2. Gather materials and place them in two different areas of the room.

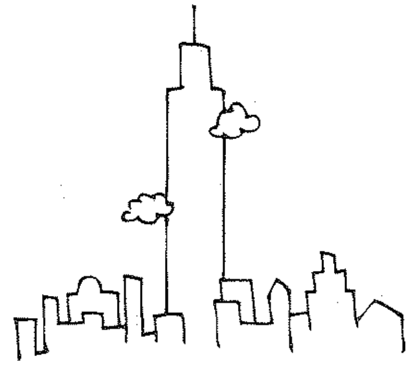
3. Bookmark websites to be used in class.
   a. http://www.emporis.com/statistics/worlds-tallest-buildings
   b. http://www.pbs.org/wgbh/buildingbig/skyscraper/basics.html
   c. http://www.madehow.com/Volume-6/Skyscraper
   d. http://dsc.discovery.com/videos/we-built-this-city-new-york-skyscrapers.html
   e. http://science.discovery.com/videos/build-it-bigger-season-4-design-of-al-hamra.html

Activity Procedure

1. Introduce skyscrapers through images and information found at Link a.
2. Discuss the "Skyscraper Basics" from Link b.
3. Discuss how the advancement of materials and the invention of elevators changed the design of skyscrapers.
4. Discuss how design elements associated with skyscrapers can be seen in nature. Discuss what natural elements could influence or be incorporated into skyscraper design and construction.
5. For more detailed information on skyscrapers' history and design, go to Link c.
6. Distribute the activity sheets.
7. Show a video (03:00) on New York skyscrapers at Link d. to incorporate an understanding of the history and nature of the skyscrapers.
8. Discuss the design elements of the foundations of a skyscraper. Use a video of Al Hamra Tower (02:13) at Link e.
9. Review the team challenge with students and answer any questions they may have. For this challenge, students' structures are judged on two criteria: height and load-bearing capability. Each team's skyscraper will earn 1 point per inch of height from the base, and 1 point per unit of weight (e.g., golf ball, penny) to be placed on the top.
10. After the team challenge has concluded, have students finish their activity sheets.
11. If you wish, assign one of the activities suggested in Extend the Learning With Skyscrapers: Activities.

Name: ______________________________ Date: ______________

Scrapers in the Sky



GOAL

- Build the tallest freestanding skyscraper that will hold the most weight.

MATERIALS

- Newspaper
- Two pieces of 9"x 12" construction paper per team
- Tape
- Golf balls, pennies, or other weight

TIME TO CREATE

- 20 minutes

INDIVIDUAL ACTIVITY

Read the following and highlight the important information, and then answer the questions.

If you're walking in the center of a major city, you'll notice very tall buildings all around you. These buildings are known as skyscrapers. The first known grand construction was the Great Pyramid of Giza. Created around 450 B.C., the Great Pyramid of Giza was the tallest structure in the world for approximately 2,400 years, or until the 19th century during the Industrial Revolution. Fundamental changes in metal manufacturing occurred during the Industrial Revolution when two new lighter, yet sturdy, materials were developed: iron and steel.

Iron and steel allowed for new designs of very tall buildings. The 10-story Home Insurance Building in Chicago was the first "skyscraper" to be built using a steel frame. With lighter materials, even taller buildings could be designed, which brought to light a new problem: the wind. Engineers had to find ways to prevent the wind from causing the buildings to sway. Today's tallest skyscrapers are required to be 50 times stronger against wind elements than were the skyscrapers of the 1940s.

Strong foundations make it possible for skyscrapers to stand on the ground and are a significant element to the design. The location and the soil of a foundation must be large enough and strong enough to support a skyscraper. Therefore, the foundation is a significant component when considering the design. Geotechnical engineers are able to dig down to reach bedrock for better support; and in coastal areas, where the bedrock lies very deep under ground, concrete piles (long rods of concrete) are driven into the ground with a large diesel hammer until they hit the bedrock.

Several skyscrapers are famous for their height. The Willis Tower (formerly the Sears Tower), built in 1974, is 442 meters (1,450 ft) tall and has 110 floors. With 101 floors, Taiwan's

Taipei 101 is 448 meters high and has an additional 508-meter spire (1,676 ft). In 2010, the Burj Khalifa, in Dubai, United Arab Emirates, standing at 828 meters (2,717 ft) with 160 floors, claimed the title of the tallest building in the world.

Extensive planning must take place when designing any building. In addition to considering the design and materials of a structure, engineers need to think about the center of gravity, weight distribution, base width, base support, surface area, and wind resistance.

1. What is the difference in height between the Burj Khalifa and the Willis Tower? ____________
2. Besides the wind, what other concerns do engineers face when designing a building? _____

   ____

3. Towers used to be constructed of heavy stone. The rooms were dark and cramped, because windows would have weakened the structure. How have materials changed the design of tall structures? ____

   ____

4. How might engineers use the shape and function of natural forms in buildings? __________

   ____

TEAM CHALLENGE

Participants will work together in teams of two or three for a total of 20 minutes to design and build the tallest skyscraper possible with newspaper (can be cut, torn, or folded). The tallest skyscraper that will hold the most weight at the top will win. Each team's skyscraper will earn 1 point per inch of height from the base, and 1 point per unit of weight (e.g., golf ball, penny) to be placed on the top. The skyscraper must be mobile (so that it can be carried to the challenge site) and sturdy enough to hold weight at the top. Tape can only be used to attach paper to paper. Measure the height of the your skyscraper and test for sturdiness.

Once teams are selected, your teacher will begin the time. You will have 20 minutes to gather your materials and build your skyscraper. Once your teacher signals that time is up, you must stop working immediately and bring your skyscraper to the challenge site. Any team that continues to work after time has been called may be disqualified.

Start Time _____ : _____ + 20 Minutes = _____ : _____ End Time

After the team challenge, answer the following questions.

1. Why did you select the shape of your skyscraper? ______________________________

   ____

2. Did you consider design elements visible in nature as you designed your skyscraper? How did this help you, or how could it have helped you? ____________________________

   ____

3. How tall was your skyscraper, rounded to the nearest tenth of an inch? ________________

4. How many units of weight was your skyscraper able to hold without toppling over? ______

5. What happened when your skyscraper was tested? ________________________________

____

6. What would you do differently if you were to build another skyscraper? Why? __________

____

7. Consider the following concepts: center of gravity, weight distribution, base width, support of base, surface area, and wind resistance. What might be some basic rules of skyscraper design regarding two of these concepts? ______________________________

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8. How might skyscrapers change in the future? ___________________________________

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9. How might skyscrapers be designed to protect against earthquakes? ___________________

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EXTEND THE LEARNING WITH SKYSCRAPERS: ACTIVITIES

1. **Skyscraper challenge.** Take on the role of an engineer at Ace Forensic Engineering Lab by visiting http://www.pbs.org/wgbh/buildingbig/skyscraper/challenge/index.html. Your job is to investigate skyscraper emergencies and then solve the problems that caused those emergencies.
2. **Forces affecting skyscrapers.** Learn about the different forces that affect skyscrapers by visiting http://www.pbs.org/wgbh/buildingbig/lab/loads.html. After the lesson, investigate forces in the site's interactive lab that simplifies the real-life forces that affect structures.
3. **Wind resistance.** Learn how engineers design skyscrapers to resist wind by visiting http://www.pbs.org/wgbh/buildingbig/skyscraper/wind.html. Write a one-paragraph summary about wind resistance and skyscrapers.
4. **Interactive skyscraper maps.** Visit http://skyscraperpage.com/cities/maps to learn more about specific skyscrapers using interactive maps. Buildings marked on a map can be clicked to open their information pages, and special controls allow you to customize what is shown on each map. Do you see patterns in where certain skyscrapers are built? Write a paragraph about what you learn at this site.
5. **Earthquake city simulation.** Build a city (with sugar cubes, bouillon cubes, and gelatin cubes) to put through simulated earthquakes to show the damage earthquakes can cause to buildings.
   1. Create a grid on large piece of cardboard by drawing four vertical lines and five horizontal lines. Each line should be 5 cm apart.
   2. Label the vertical lines 1st Avenue, 2nd Avenue, and so on, and label the horizontal lines A Street, B Street, and so on. This is the street grid of your city.
   3. Build three sugar-cube skyscrapers, each one five sugar cubes tall. Build the skyscrapers at the following corners: A and 1st , B and 2nd, and C and 3rd.
   4. Simulate an earthquake by tapping on the corner of D and 4th with the eraser of a pencil. Continue to tap until at least one cube from each skyscraper falls.

      Which skyscraper fell first? ______________________________

      ____

      ____

In a real earthquake, would more damage happen in one place than another? Where would the most damage happen?

____

____

____

5. Try the previous step again, reassembling the sugar cubes, but use different-strength taps to represent hard vibrations and soft vibrations. Determine how many hard or soft vibrations it takes to knock over buildings different distances away from the earthquake's epicenter.
6. Record your results in a chart containing the locations of the skyscrapers and when each fell.
7. Build a city of skyscrapers. Skyscrapers should include varying heights. Experiment with different types of cubes and designs. Try the pencil-tap test at a corner in the city to test the structures' ability to resist earthquakes.