FORCES

AT A GLANCE Explore the various forces at work in a structure. What kinds of forces act upon a building? How can we demonstrate these forces?

OBJECTIVES:

Students will:

- Describe the structural forces that act upon an object.
- Determine which materials withstand the most compression and tension.
- Explain live and dead loads.

KEY VOCABULARY

Structure, Compression, Tension, Bending, Torsion, Load, Live Load, Dead Load

NEXT GENERATION SCIENCE STANDARDS

Science and Engineering Practices:

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigations
- Constructing explanations and designing solutions
- Obtaining, evaluating and communicating information

CROSSCUTTING CONCEPTS

- Cause and effect
- Energy and matter

DISCIPLINARY CORE IDEAS

- PS3: Energy
- ETS1: Engineering design
- ETS 2: Links among engineering, technology, science and society

PACE YOURSELF:

* Two 30-minute periods

museum of science+industry chicago

ADVANCE PREPARATION

Collect a wide variety of materials on which the different structural forces can be tested.

MATERIALS

Per group:

- Chair
- Scissors
- Samples of six to eight different materials, such as yarn, craft sticks, straws, pipe cleaners, clay, rubber bands, pencils, etc.
- A piece of cloth or rag

Per Student:

- Student worksheet

WHAT YOU NEED TO KNOW

There are a variety of forces at work in structures. A force is a push or a pull that transfers energy into an object. Structures are subjected to both internal and external forces that need to be considered by engineers and architects as they design safe and lasting structures.

Compression is a force that pushes or squeezes materials. A material under compression may be shortened or crushed. Tension is a force that pulls and/or stretches materials. When a material is bent, one side is in tension while the other is in compression. Engineers must either prevent bending in their structures or select materials that can withstand both tension and compression. Two other important forces acting upon structures are shear and torsion: shear is a force that causes parts of a material to slide past one another in opposite directions, and torsion is a twisting force.

The weight of a structure is referred to as its load. Dead load is the weight of the structure itself (the walls, floors, windows, internal beams, etc) acting with gravity on the foundations below. Live load is the weight that is added to the structure, such as furniture or people, and also the more temporary external forces of wind, snow, earthquakes and traffic. This load changes over time.

Different materials have different abilities to withstand these forces. Understanding which materials best withstand each force is critical when designing structures. Materials that serve as horizontal parts of structures, such as floors and bridge decks, should be able to withstand bending. Materials that are vertical parts of structures, such as walls and bridge abutments, should be able to withstand compression.

WARM UP

1. Place a chair in the middle of the floor. Are there any forces acting upon it?
2. Gently push the chair a long distance. What forces acted upon the chair? A push created an unbalanced force that made the chair move.
3. Repeat this last step, this time having a second person pushing back on the chair so that it does not move. What forces are acting on the chair? Why does it not move? Two forces are acting on the chair, but they are balanced. Ask the students to think back to the first step. When no one is pushing on the chair are there still equal forces acting upon it?

ACTIVITY

Explain to the students that in any building, from a house to a skyscraper, there are forces acting upon it. Ask the students if they know what a force is. When talking about structures, a force can be defined as a push or a pull. There are a few main forces that act upon every structure.

Tension

1. Give each student a rubber band. Tell them to pull the rubber band with their hands. What happens? It stretches out, gets longer and the material gets thinner. The rubber band is being pulled; this is called tension.
2. Have two students link fingers and lean away from each other. How do their arms feel? Do they feel stretched? Tension is the stretching force that pulls on a material.
3. Can you name parts of structures in the real world that are under tension? Elevator cables and the cables on suspension bridges are parts of structures that are in tension.

Compression

1. Show the group a large sponge. Pass the sponge around and have a few students push down on top of the sponge. Ask them: What happens? The sponge gets smashed down, it gets shorter, and it bulges in the middle. The sponge is being pushed or being compressed.
2. Have two students place their palms together and gradually lean in toward each other. How do their arms feel? Do they feel squeezed or pushed together? Compression is the pressing force that squeezes a material together.
3. Can you name parts of structures in the real world that are under compression? Columns and bridge abutments are parts of structures that are under compression.

Torsion

1. Have two students grab the opposite ends of a piece of cloth, and start turning that cloth in their hands in opposite directions from one another. What happens to the cloth? Torsion is the twisting force that acts upon structures.
2. Can you predict what would happen to a bridge deck under torsion?

Load

1. Have students look around the room and make a list of all the different loads that they can find.
2. As a class, make a T-chart dividing the lists of loads into two categories: dead loads and live loads. Dead loads include the weights of the walls, ceiling, floor and any permanent structures such as light fixtures, doors and windows. Live loads include things that are not fixed, such as furniture, pictures, people and the rain or snow that might be pounding the building outside.

Material's Strength

1. Give each group of students six to 10 samples of various materials.
2. Ask students to predict which materials will best be able to withstand tension, compression and torsion.
3. To test tension, pull on the object from each end.
4. To test compression push the object from each end.
5. To test torsion, grab each end of the object and turn it in opposite directions (twist it).
6. Which materials withstood the forces best? Which ones broke easily?
7. Can you think of a material that would be able to withstand both tension and compression?
8. Does the shape of the material impact how strong it is? Try adapting an object to test this.

CHECK FOR UNDERSTANDING

Have students answer the following questions in their teams or as a whole group discussion.

- What types of forces act upon a structure?
- Why is it important to use the right material to build a structure?
- What is the difference between live and dead load?

WHAT'S HAPPENING

Forces (like tension and compression) that work on a building need to be equally distributed throughout the structure. This means the building must have a strong foundation and use strong shapes throughout.

Shapes like triangles are very strong because they distribute weight evenly from the points to the base. Triangles also keep their shape even under enormous pressure.

DIFFERENTIATED INSTRUCTION

For English learners, build a word wall with the vocabulary words for this lesson. Have students create their own flash cards with the definition of the term on one side, and a drawing of it on the other.

EXTENSIONS

- Sometimes the forces acting upon a structure are stronger than the structure itself. Research structures that have been unable to withstand the forces exerted on them. What happened? Was the structure re-built? If so, how was the design of the structure changed to made it more structurally stable?
- List the materials from the Materials' Strength section according to whether they were good under compression or good under tension. What do all the tension materials have in common with each other? What do all the compression materials have in common with each other? What characteristics do the materials from both groups share? Construct a Venn diagram to answer these questions.
- Look at pictures of various buildings and have the students draw or tape "Force Arrows" for tension, compression and torsion to show where forces are acting on each one.

FORCES STUDENT WORKSHEET

NAME _____

1. What is the main effect of tension on a material?

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2. What are some parts of real world structures that are under tension?

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3. What is the main effect of compression on a material?

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4. What are some parts of real world structures that are under compression?

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5. What force is acting upon the cloth that was twisted?

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6. Can you predict what would happen to a bridge deck under torsion?

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7. What force is exemplified by scissors? Briefly explain the interaction of forces that make a pair of scissors work.

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8. Make a list of all the different loads you can find in your classroom, and circle if it is a “dead” or “live” load.

Load _____ DEAD LOAD LIVE LOAD

Load _____ DEAD LOAD LIVE LOAD

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Load _____ DEAD LOAD LIVE LOAD

Load _____ DEAD LOAD LIVE LOAD

Load _____ DEAD LOAD LIVE LOAD

Load _____ DEAD LOAD LIVE LOAD

9. List materials that are strongest in each of these forces:

TENSION	COMPRESSION	TORSION

10. Which materials withstood the forces best? Which ones broke easily?

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11. Can you think of a material that would be strong in both tension and compression?

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12. Does the shape of the material impact how strong it is? Try adapting an object to test this.

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