5.1 Stabilizing Structures

Here is a summary of what you will learn in this section:

- A structure is stable if forces are balanced.
- Unbalanced forces can cause stress and fatigue in structures.
- Proper materials can be used to stabilize structures.
- Building techniques can be used to stabilize structures.

Figure 5.5 When the shelf looks bent, it is under stress.

Most of us have sat on a wobbly seat at some time in our lives. Every time you shift in your seat, you get a little wobble. You could fold up some paper or cardboard and put it under one of the legs of the chair. Why does this stop the wobbling? Because you have balanced the chair.

You might have seen a bookcase shelf that sags in the middle. The sag shows that the structure is having trouble withstanding the weight of the books. What you can do to fix the sag depends on your situation. You could take some of the books off. However, if you have no other place to put the books, you might have to strengthen the bookcase itself (Figure 5.5).

In this section, you will look at what happens when structures are unstable and explore ways of stabilizing them.

B23 *Starting Point* Skills A C

The Tipping Point

Hold your arms out in front of you at chest level, palms up, making a platform with your arms. Have a classmate put one textbook on your arms near your palms. Do you feel a slight urge to put your arms down? Have the classmate put another textbook on top of the first. Is the urge stronger? How many textbooks do you think you could support like this? In the end, would adding just one book cause you to drop all of the books? What if your classmate stopped at two textbooks? How long do you think you could hold your arms up?

Structural Strength

Some structures seem to stand the test of time. You may have seen the Colosseum in Rome or the pyramids of Egypt on television. These structures were built thousands of years ago and are still standing. On the other hand, some buildings may have to be demolished less than a century after they were built, because they have become unsafe (Figure 5.6).

Figure 5.6 Some structures last thousands of years while others do not.

Structural Shapes

Some of the strength of a structure lies in the shapes used in its design. You may have heard that the triangle is a very strong shape and is found in many structures. Squares and rectangles are not as strong as triangles. Three-dimensional triangular prisms and pyramid shapes are also stronger than three-dimensional rectangular prisms.

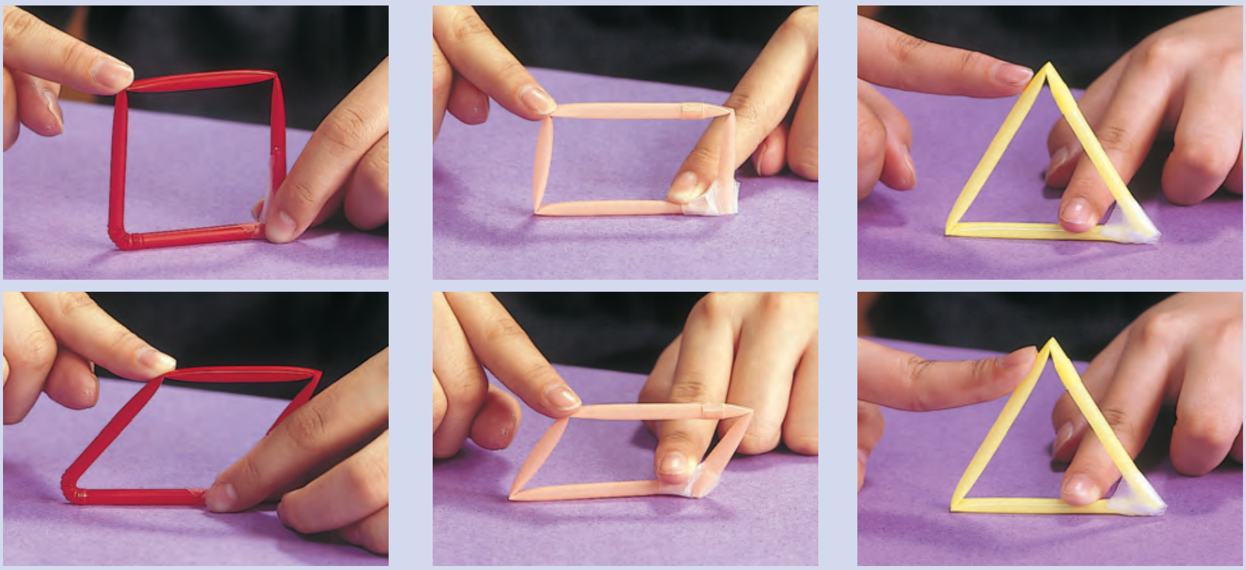
B24 *Learning Checkpoint*

Triangular Strength

Triangles are stronger than squares. Test this out for yourself using a few straws and some tape.

Bend one straw into a square (Figure 5.7a), one into a rectangle (b), and one into a triangle (c). Tape the ends of each straw together.

Rest each structure upright on the table. Gently push in the same plane as the shape on an upper corner of the structure. Which is the strongest?



(a) (b) (c)

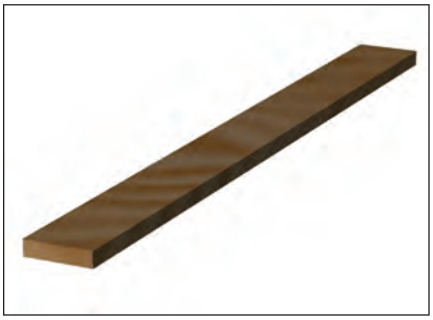
Figure 5.7

Structural Components

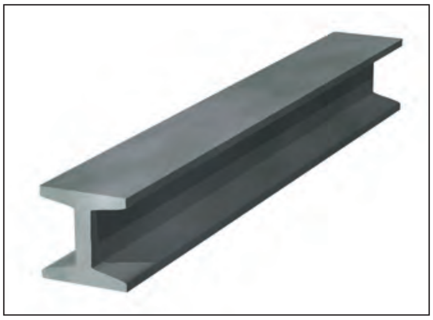
Suggested Activity
B27 Inquiry Activity on page 138

When you look at buildings, notice that many of the same features appear in many different buildings. Arches, beams, and columns are used over and over again in building design because these **structural components** can add strength. Also, many people find them aesthetically pleasing. Several different structural components are shown in Figure 5.8.

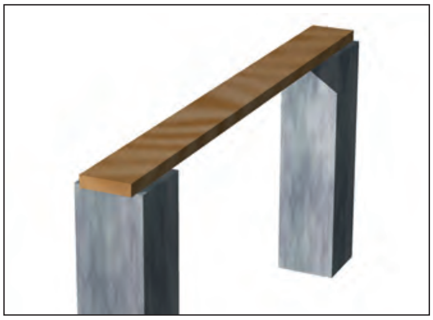
Figure 5.8 Structural components



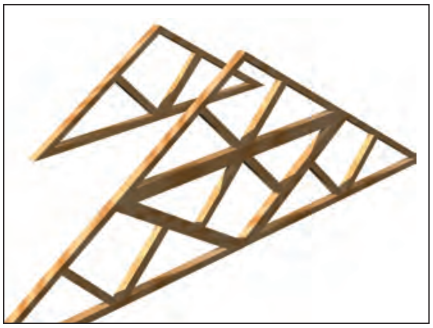
A **beam** is a flat structure that is supported at each end. If too much weight is put on a beam, it will bend in a u-shape or even break in the middle.



An **I-beam**'s shape gives it strength. I-beams have less weight than solid beams of the same length. Because they have less of their own weight to support, I-beams can support larger loads.



A **column** is a solid structure that can stand by itself. Columns can be used to support beams and I-beams.

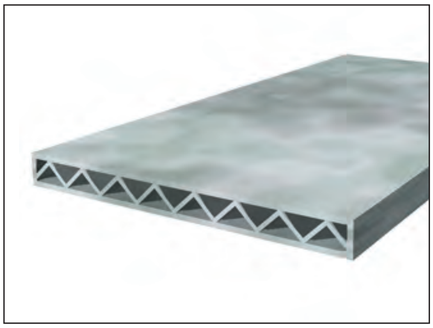


A **truss** is a rigid framework of beams joined together. Trusses are usually in the form of interlocking triangles.

A **cantilever** is a flat structure that is supported only at one end. When weight is placed on the other end of the cantilever, the cantilever bends in an n-shape to resist the load.

Girders, or **box beams**, are long beams in the shape of hollow rectangular prisms.

An **arch** is a curved structure that can support a lot of weight. The force of weight on an arch is carried along the sides of the arch to its supports. This spreads out the effect of any load.



When a sheet of metal or cardboard is shaped into a series of pleats or triangles, it is called **corrugated metal** or **corrugated cardboard**. A corrugated sheet is stronger than a flat sheet.

Figure 5.9 The Hockey Hall of Fame in Toronto

Structural components can be used alone or in combination. For example, the windows and door of the Hockey Hall of Fame building (Figure 5.9) are in the shape of an arch. The arch shape spreads the force of the load through both sides of the arch and into the foundation. The columns between the windows support beams on top. The triangle above the beam is similar to a truss.

Structural Materials

Imagine two bookcases, one of tissue paper and one of concrete. Both seem silly, but for different reasons. A tissue paper bookcase would be too flimsy to withstand the load of the books. A concrete bookcase would be strong but heavy and difficult to move. It is important to choose appropriate materials when designing and building structures.

Take It Further

Wood is an important building material. It is renewable if managed properly and can be used for many different structures. Recently, bamboo, a type of grass, has become a popular building material. Find out more about its advantages and disadvantages. Begin your search at ScienceSource.

Centre of Gravity

Can you balance a ruler on one finger? The only point where this can happen is at the exact middle of the ruler. Each half of the ruler is exactly the same, or symmetrical. This point is called the **centre of gravity**. The centre of gravity is the point at which a body's mass is concentrated. The body is equally balanced in all directions at this point.

Every structure has a centre of gravity. This is the point that gravity seems to act on. The location of the centre of gravity in a structure helps to determine how stable the structure is. Think of a chair (Figure 5.10 on the next page). When you sit on the chair, the centre of gravity of the chair plus the human is different from those of the chair and the human by themselves. That is why some stools tend to tip over only when someone sits down on them.

Suggested Activity
B26 Quick Lab on page 137

Figure 5.10 The legs of the highchair are more splayed than those of an ordinary chair because its centre of gravity is higher. The splayed legs make the highchair more stable.

Figure 5.11 The clown falls over when you punch it, but returns to its upright position quickly. The clown did not really knock the person down!

Stability

Stability depends on materials and construction techniques as well as the centre of gravity. A table has a high centre of gravity but is usually stable if it has four legs relatively far apart. The closer together the legs are, the less stable it becomes. Stability is also determined by whether the structure is solid, frame, or shell — a solid structure with a high centre of gravity can be less stable than a frame table is.

Some structures are designed to be unstable (for example, the clown punching bag in Figure 5.11). Others are designed to be weak like the front ends of cars and the water-filled plastic barrels at highway off-ramps that absorb a lot of energy (Figure 5.12). Other objects, such as bales of straw, can also absorb energy (Figure 5.13).

Figure 5.12 A car would lose a lot of its energy hitting the barrels. It would be a lot less damaged than if it hit the pillar directly.

Figure 5.13 Many racetracks use bales of straw to protect the drivers and the audience from crashes.

When Things Go Wrong

Structural Stress and Fatigue

When a structure is poorly designed or built, it may not be able to withstand all of the forces it has to face. When a structure has to face large combinations of internal and external forces over a long period of time, the structure might weaken. This may result in **structural stress**. At first, signs of structural stress may disappear when the internal and external forces are reduced.

Figure 5.14 This old house shows structural fatigue. However, it may take several more wind storms before it fails completely.

For example, if you place an abnormally large book on the middle of a bookshelf, the shelf might bend. The bend in the shelf is a sign of stress. When the book is removed, the shelf may go back to its original shape. However, if the shelf cannot withstand the stress, it might crack. Permanent changes, like the bookshelf cracking, are signs of **structural fatigue** (Figure 5.14).

WORDS MATTER

"Fatigue" means extreme tiredness. Both people and structures can be fatigued or tired out.

Structural Failure

If you ignore the structural fatigue and place more large books in the middle of the shelf, the shelf may collapse. This is called structural failure. **Structural failure** is the breakdown of a structure due to the internal and external forces acting on it. However, in this case, the failure would not be a surprise. The structure had already shown structural stress by bending, structural fatigue by cracking, and finally structural failure by collapsing.

Take It Further

Demolition companies use several methods to demolish structures. Small buildings are bulldozed, very large buildings are imploded. Find out about these businesses, the equipment and procedures they use, and their safety records. Start your search at ScienceSource.

B25 *During Reading*

Thinking Literacy

Inferring

Sometimes the answer to a question can't be found in the text. Readers often have to draw conclusions using what they already know and new information or clues from the text to answer a question. This is called inferring or making an inference.

Have you ever heard the expression "It was the straw that broke the camel's back"? How could something as light and as small as a straw break a strong animal's back? Think about this and relate it to the activity you did with the textbooks on your arms. Share your inference with a partner.

Product Recalls

Despite all of the planning that goes into new structures, sometimes flaws are not discovered until the product is sold to the public. When the flaws are serious, manufacturers use a **product recall**. The manufacturers contact the media, who broadcast the recall on the news. They may also use their own advertising to alert the public. Consumers can take the affected product back to the store for a refund, for exchange for another model, or to have the affected structure fixed.

Sometimes, it is an issue with the materials used. For example, some children's toys have been recalled because it was discovered that the paint had high levels of lead (Figure 5.15). Lead can cause brain damage.

Figure 5.15 Because children often chew on their toys, the paint must not contain lead.

Sometimes, parts of a larger structure break off too easily. This is also a concern with toys because small parts can be choking hazards.

Child and baby car seats have been recalled when harnesses have been found to be faulty. A large video game company re-issued the safety straps on their popular controllers because the original ones broke under regular use. And thousands of owners of laptop computers got new batteries when the batteries in some of the computers overheated or burst into flames.

Car Recalls

Cars are often the subjects of recalls. In this case, the owners take their cars back to the dealership for the necessary repairs at no charge to them.

Several years ago, a car model was recalled because of a poor design: its gas tank was too close to the rear end. If these cars were rear-ended, they often burst into flames. The bad design cost several people their lives. The manufacturer had to replace vehicles with the flaw and pay compensation to the injured and the families of the deceased. As well, the news reports were very bad publicity for the company. As you can see, it is better to design well in the first place than to pay for bad design later on.

B26 Quick Lab

Stability

Figure 5.16 Candles come in many shapes. Some are less stable than others.

When you balance something like a ruler, it is simple to find the centre of gravity. Usually, however, the centre of gravity is not as obvious. It is not always easy to determine the centre of gravity of an object, but generally speaking, the lower the centre of gravity is on an object, the more stable the object is.

Some of the candles in Figure 5.16 have a small base and a high centre of gravity. They are more likely to tip than shorter, fatter candles are.

Purpose

To investigate the centre of gravity of a variety of structures

CAUTION: Handle sharp objects like scissors very carefully.

Materials & Equipment

- pencil and paper for recording
- ruler
- scissors
- paper for constructing
- tape

Procedure

1. Roll one piece of paper into the shape of a fat cone and tape it closed.
2. Roll another piece of paper into a thinner cone the same height and tape it closed.
3. Roll a third piece of paper into an even thinner cone, also the same height, and tape it closed.
4. Cut the bottom of each cone so that it can stand on the table with the pointed side up.
5. Test to see which cone is the most stable by trying to tip each one over.
6. Record your results.
7. Make three cylinders with different widths but the same height as your cones. Repeat steps 5 and 6.

Questions

8. Which cone was the hardest to tip over? Why? Compare your results with those of the class.
9. Which cylinder was the hardest to tip over? Why? Compare your results with those of the class.
10. Which shape was harder to tip over, cones or cylinders? Why?
11. What can you conclude about the location of the centre of gravity of each cone and each cylinder?
12. How can you use this information to build more stable structures?

B27 *Inquiry Activity* Toolkit 2

SKILLS YOU WILL USE
- Designing a fair test
- Recording and organizing data

Structural Components and Materials

When designing and constructing a structure, you need to know about structural components and materials. In this lab, you will experiment with components and materials to learn more about their properties.

Questions

1. What are the properties of some structural components?
2. What is the effect of using different materials when building structural components?

Materials & Equipment

- various types of paper
- masking tape
- scissors
- a roll of coins for testing

CAUTION: Handle sharp objects like scissors very carefully.

Procedure

Part 1 The Components

1. Look at some of the structural components in Figure 5.8 on page 132. Choose three to build using photocopy paper and tape.
2. Build your components using as little tape as possible in each case.
3. Determine how strong each component is by using your coins.
4. Record your findings on a chart like the one in Table 5.1.

Table 5.1 Results of Components Test

Name of Component	Sketch	Results

Part 2 The Materials

5. Choose one of the components you tested above.
6. Build the componenet three times using a different type of paper each time. Try to use the same amount of tape and paper for each one.
7. Determine how strong each sample is by using your coins.
8. Record your findings in a table.

Analyzing and Interpreting

9. What did you find out about components in Part 1? Compare your results with those of another group.
10. What did you find out about materials in Part 2? Compare your results with those of another group.
11. Which component resisted the forces the best?
12. Which material resisted the forces the best?

Skill Builder

13. Could any parts of this test be made fairer? Explain how.

Forming Conclusions

14. What are some of the properties of the structural components you tested? Where would this component be useful?
15. What are some properties of the materials you tested? Where would these materials be useful?

5.1 CHECK and REFLECT

Key Concept Review

1. Define "structural strength" and "stability" in your own words.
2. Briefly describe how each of the following contributes to structural strength.
   (a) structural shapes
   (b) structural components
   (c) structural materials
3. Use the words "structural stress," "fatigue," or "failure" to describe each situation below.
   (a) a bend in a plastic cup
   (b) a melted plastic cup
   (c) a hole in a plastic cup
   (d) a crack in a glass
   (e) a chip in a glass
   (f) pieces of shattered glass on the floor

Connect Your Understanding

4. Think of an ancient structure that exhibits one of the structural components. Compare it to a modern structure that uses the same structural components.
5. Think about a crumpled-up takeout paper cup. What factors could have contributed to that structure's failure?
6. Explain why a triangular shape is stronger than a rectangular shape.

Practise Your Skills

7. Think of the form and function of an inukshuk (Chapter 5 opener), an igloo (Figure 4.11), and a kayak (Figure 5.17). Choose one of these structures and do the following.
   (a) Draw a diagram to show its form.
   (b) Label any structural components present in the structure.
   (c) Describe the materials that are used to build it.
   (d) Repeat (a) to (c) for a structure of your choice.

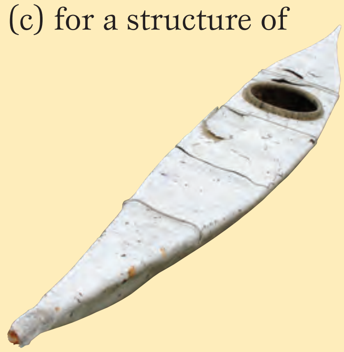


Figure 5.17

8. Use commercial building materials such as interlocking blocks to build the tallest stable structure you can. Measure its height. Dismantle the structure. Using the same pieces, try to make the structure even taller. Is the second structure as stable as the first?

For more questions, go to ScienceSource.

B28 *Thinking about Science, Technology, and Society*

News Flash

Think about a recent product recall you heard about on the news. Determine the issue that prompted the recall. With a group of classmates, discuss the product recall. Use scientific terms from this chapter in your explanation.