Chapter G: More Loads and Forces

AIMS & OBJECTIVES

- To understand the **forces** that act in bridges and structures
- To recognise and describe **shear** and **tension**
- To show that forces must be balanced for a structure to stand

CONTEXT

You cannot see a force, but you can see the effect of a force. When a force is acting on an object, it can change its shape, speed or direction of movement. For a structure to stay standing and functional, the forces and loads exerted on it and within it must be balanced.

LANGUAGE OF BRIDGES:

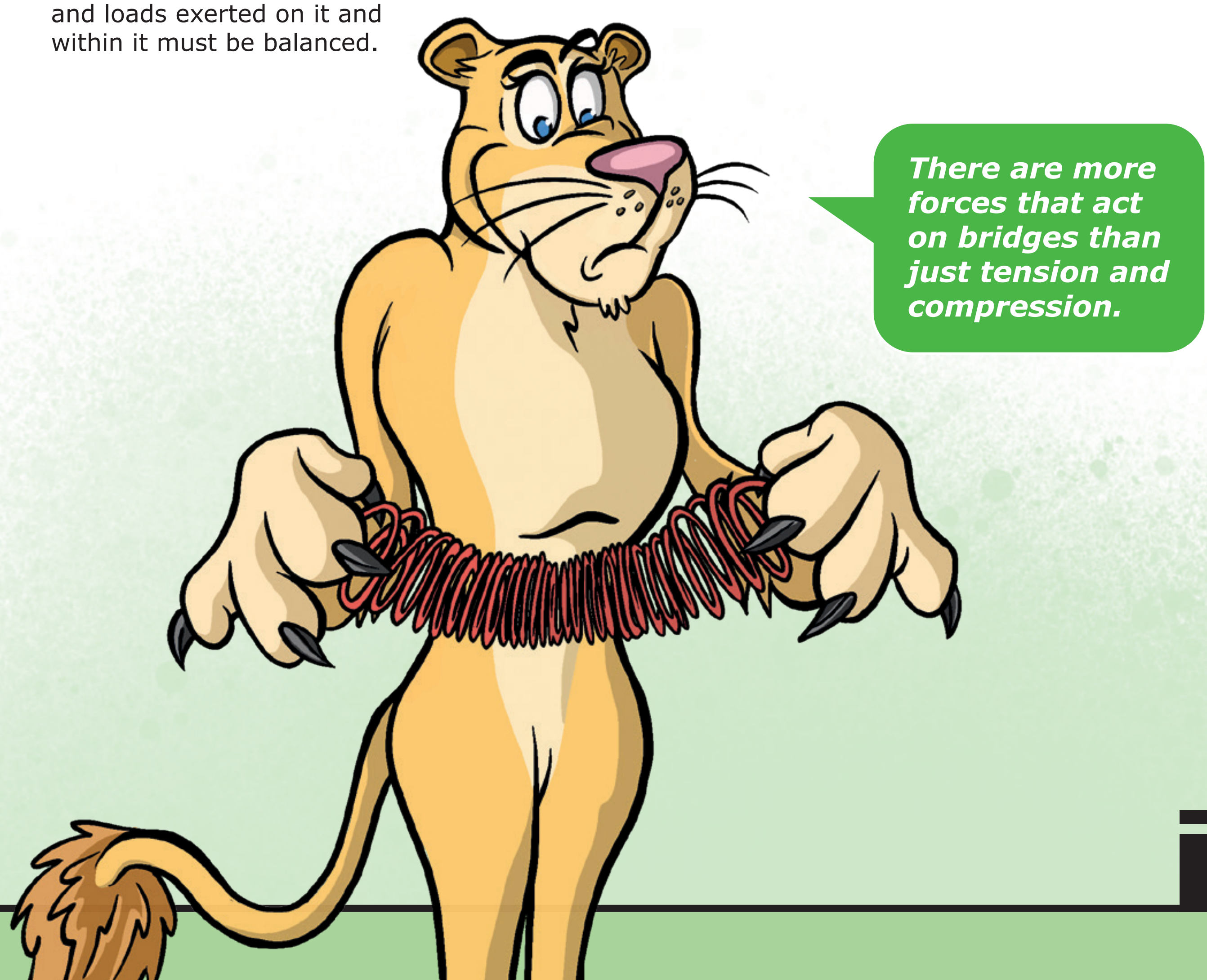
Compression: a force that tries to make things shorter or smaller (a squashing, pushing force).

Shear: a sliding force which occurs when an object is being pulled in two different directions.

Tension: a force that tries to make things longer (a stretching, pulling force).

Transverse: something at right angles, or crossways, to something else.

Torsion: a twisting force. This is caused when either end of the object is being moved in opposite directions.



You will need...

- Slinky spring
- Large sponge (such as used for car cleaning), marked along the side with a marker pen, with vertical lines, approximately 2.5cm apart
- Scissors with long strips of thin card
- Deck of playing cards
- Piece of paper

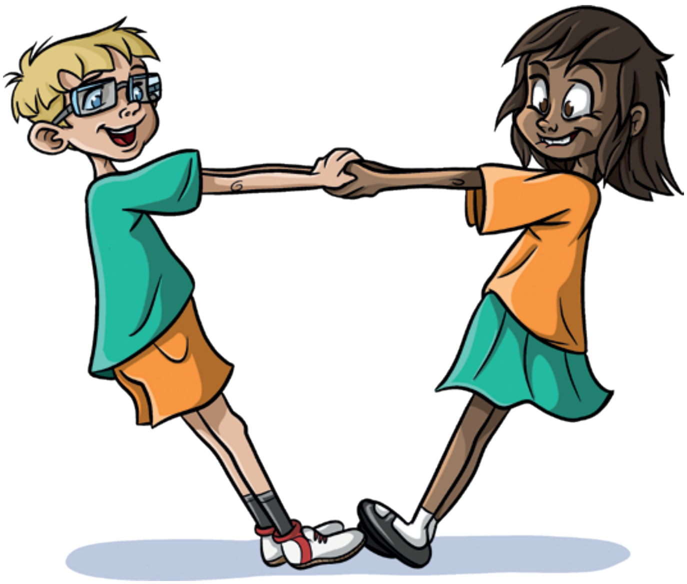
Photo by Adam Valstar on Unsplash

- Towel/cloth, bowl of water
- Bridge building challenge, per group:
  - Range of every day materials: for example, string, Lego® bricks, uncooked spaghetti, cardboard tubes, bread rolls, cardboard boxes
  - Handout: *Testing everyday objects record sheet 2*
  - Range of 'building' materials, such as household recycling, cardboard boxes and tubes, string
  - Sticky tape
  - Ruler
  - Weights, such as nuts/ washers, thin books
  - Desk fan

Something to Try:

In Learning about Bridges, the loads that cause forces inside the bridge were explored. The following activities you can try to demonstrate the forces of tension and compression:

Tension: Using a "Slinky" spring, pull from each side. This force is tension which always tries to make things longer. Think of it as a stretching force. Ask the learners to hold hands in pairs and pull. Feel the tension.

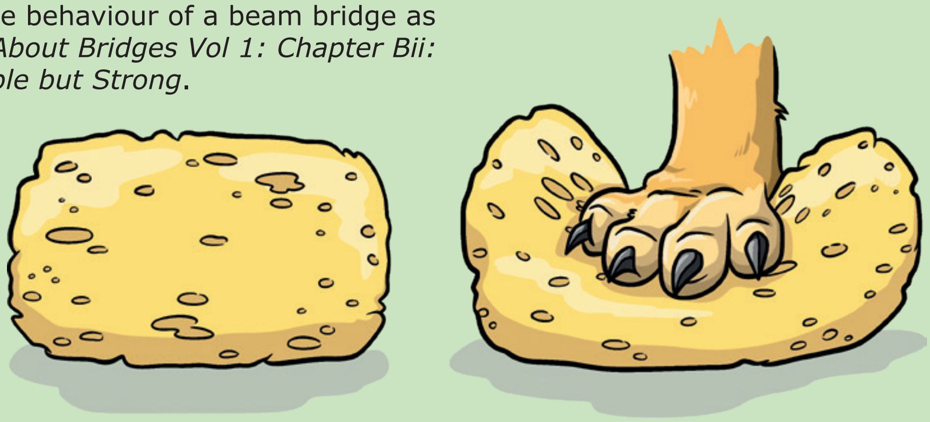


TENSION

Compression: Using a sponge, push down hard. This force is compression which always tries to make things shorter or smaller. Think of it as a squashing force. The lines on the sponge help demonstrate the effect of the force: you should notice that as the force is applied, the lines get closer together, at the top of the sponge particularly. If the sponge is firm and large enough, you might notice the lines spread out a little along the bottom, although get closer together along the top edge.

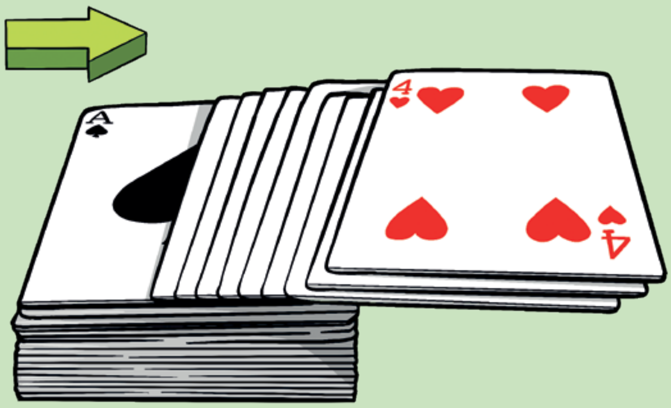
This demonstrates the behaviour of a beam bridge as covered in *Learning About Bridges Vol 1: Chapter Bii: Beam Bridges – Simple but Strong*.

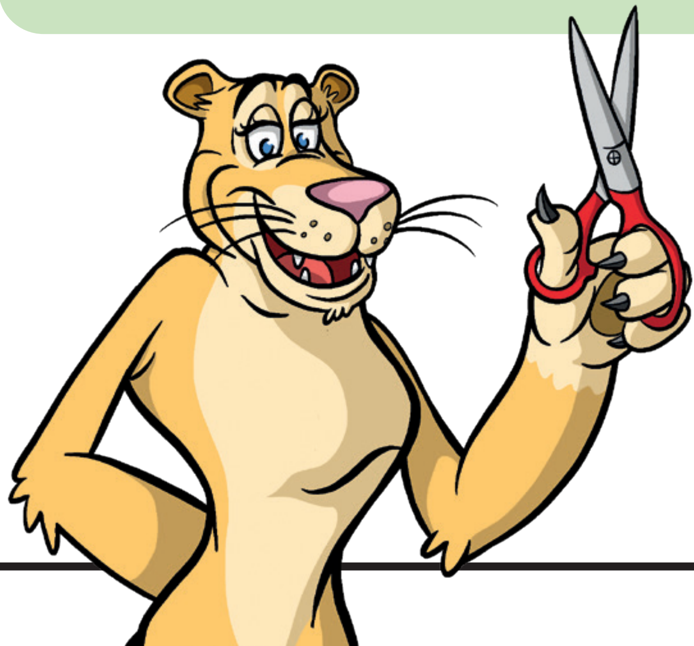
LINK



Shear force happens when an object is being pulled in two different directions, when part of the object slides across another part. This can be caused in bridges by high winds or floods, when one part of the bridge is affected by the force in one direction, and another in a different direction.

This can be demonstrated with a pack of cards. Simply stack the cards in a single pile, and then gently, just using a finger, push sideways on the top part of the stack. Ask learners what they notice happening.



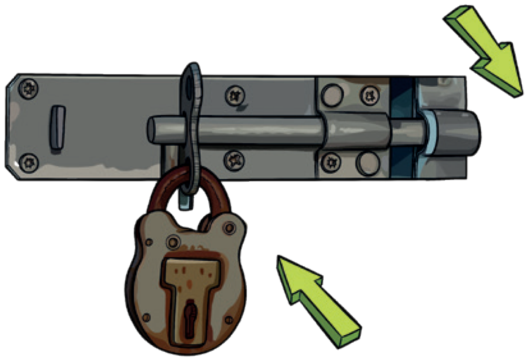


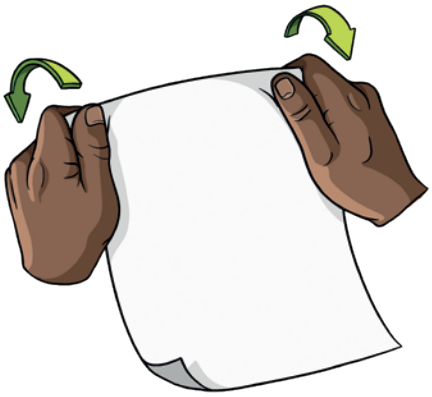
When scissors are used to cut a sheet of paper, this is using shear force. The handles of the scissors move in opposite directions. They place force on the screw that joins the handles together. The blades slide to cut the paper.

In fact, shears is another name for scissor-like cutting tools.

Photo by Belinda Fewings on Unsplash

Looking at this picture of a bolt lock on a gate, ask learners to imagine what would happen if someone pushed really hard on the gate, and someone pushed really hard on the other section.

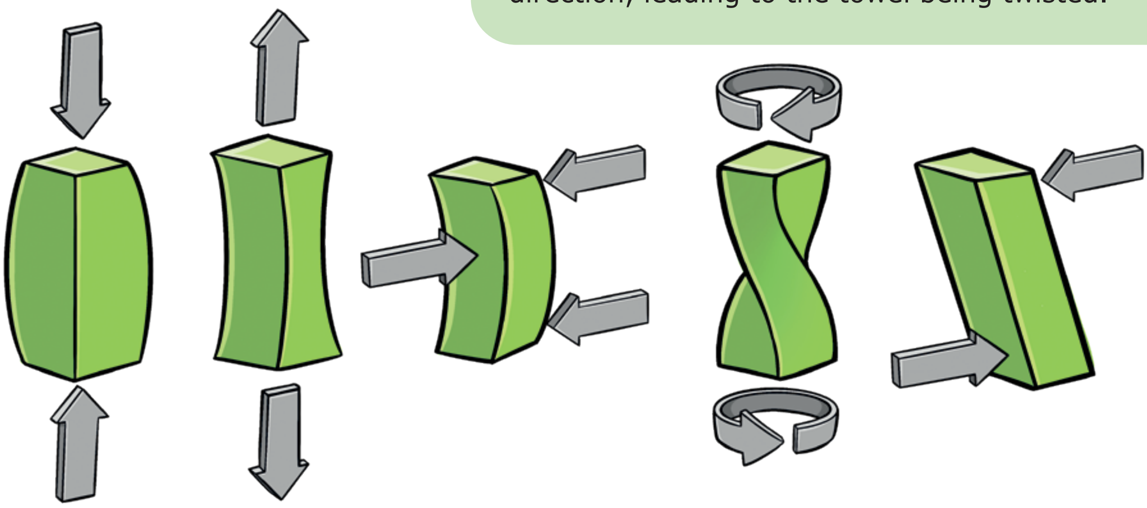




Another demonstration of this force uses a single piece of paper. Take the top two corners in your hands. Quickly push one forward and pull one back. What happens to the paper?

When the shear force (which is effectively pushing in two directions across the bolt) is applied to the gate lock, it is possible that the bolt would shear or break. This is what happens in engineering and structures: if bolts are used to fix two parts of the structure together, and a load is applied to the structure (such as high winds) that creates the shear force, the bolts can shear or break.

Torsion is a twisting force. An every day example of this is when you wring out a wet towel – each end of the towel is being moved in a different direction, leading to the towel being twisted.



Challenge Time!

Divide the learners into groups and ask them to examine a series of everyday objects, by twisting, stretching, squashing, pulling or pushing the objects. Are they stronger under tension, compression, torsion or shear?

Try string, elastic bands, a small tower made of Lego® bricks, uncooked spaghetti, bread rolls, building blocks, stickle bricks and cardboard boxes tubes for example, alongside some general 'recycling' such as cardboard boxes. Use the *Testing everyday objects record sheet handout 2* to record the outcome.

Links to *Learning About Bridges Vol 1: Chapter Aii Loads and Forces*

Use some of the same sorts of every day materials as those tested to construct a bridge. Encourage learners to think about the forces the structure will have to resist and choose the materials that will have the correct properties to withstand these forces. The aim is to build the strongest bridge, able to hold a set mass (choose a mass that most of the bridges can withstand depending on what you have available – it just has to be equal for all bridges) whilst withstanding the environmental pressure of the wind (which creates increased live load).

The bridge should span a 40cm gap. To increase the challenge in the task, you could limit the quantity or type of materials and/or sticky tape each group can use.

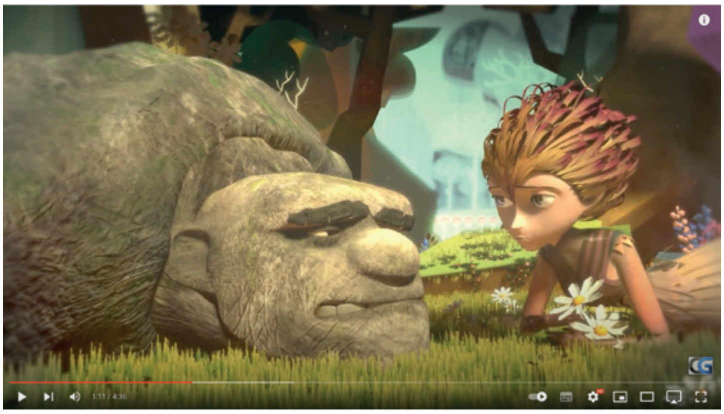
To test the bridges, position a fan to one side of the bridge, so that the air flows across the bridge. The position should be fixed, with the same wind speed, for all bridges to keep the conditions for all bridges as consistent as possible.

There is no one 'right' solution to this challenge, instead the outcome is to identify the forces applied to the structure and consider the appropriate materials and their properties for construction of the pier.

Get learners to 'think like engineers' by testing their designs and improving them to test again. This is the 'engineering design process'. **This links to page 7.**

HOT TOPICS!

In this section, we talk about shear force, and properties of materials. The Broken Team from CG Bros have produced a CGI animated short, which creates personalities for the traditional 'Rock, Paper, Scissors' game. This links to visual literacy skills, as it doesn't have any dialogue, and can be used to inspire creative projects.



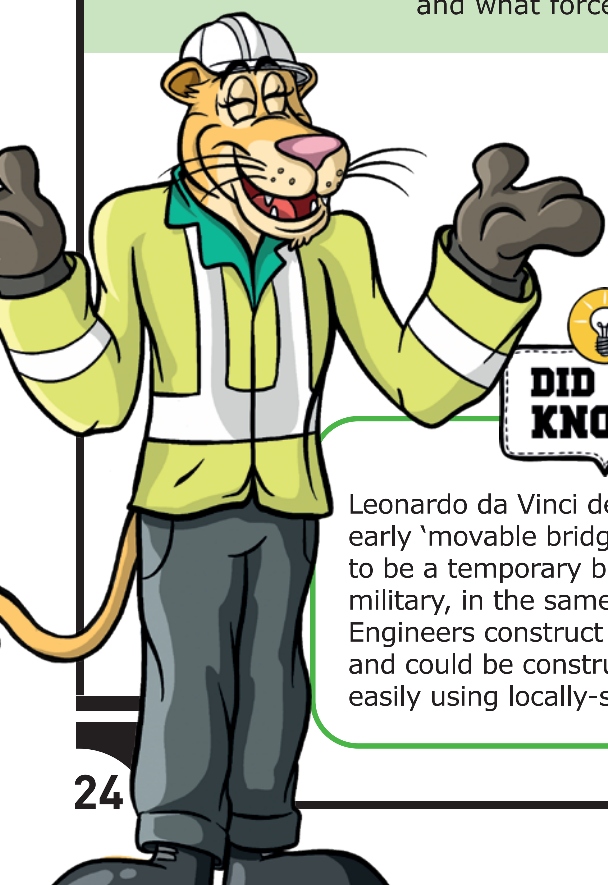
Just 4 Fun

To explore how forces balance as well as exploring the idea of the centre of gravity, you could attempt to make a balancing butterfly. Draw a butterfly on a piece of paper or thin card, and then, try to balance it on top of a pencil or small stick (use a blob of sticky tack or clay to keep the pencil standing upright). Tape a penny or attach a paperclip to the front of each wing and then repeat balancing the butterfly on top of the pencil. What do you notice about how the butterfly balances?

OUT & ABOUT

In this session, we added torsion and shear to compression and tension as forces in bridges. As you go about your daily activities, start thinking about times when you notice the forces that are acting on you or objects around you, and the effects they have. Can you identify when forces are acting and what forces they are?

Here's a model version we have at Rochester Bridge Trust.



DID YOU KNOW?

Leonardo da Vinci designed a very early 'movable bridge'. It was designed to be a temporary bridge for the military, in the same way the Royal Engineers construct temporary bridges, and could be constructed quickly and easily using locally-sourced wood.

Langdon presents:

- *Testing everyday objects record sheet 2* handout

Handouts can be found at www.rochesterbridgetrust.org.uk