

Chapter Bii: Beam Bridges – Simple but Strong

AIMS & OBJECTIVES

- To apply knowledge of forces and loads to a beam bridge
- To explain the limitations of beam bridges

CONTEXT

The earliest and simplest form of bridge was a beam bridge, but as human civilisation has developed, so has the need for longer and stronger bridges. The load of the bridge is entirely supported by the piers, and the deck is susceptible to bending: for this reason, beam bridges are used to span relatively small gaps.

LANGUAGE OF BRIDGES:

Abutment: the structure that the ends of the bridge rest on and can be anchored by.

Beam: the simplest form of bridge, consisting of a single span resting on abutments.

Deck: the main surface of the bridge, the traffic crosses here.

Parapet: a low wall or railing alongside the edge of the bridge deck to protect traffic from falling off.

Piers: the upright columns that support the bridge.

Span: the distance between bridge supports.

Total span: the full distance, from one side to the other, the bridge covers.

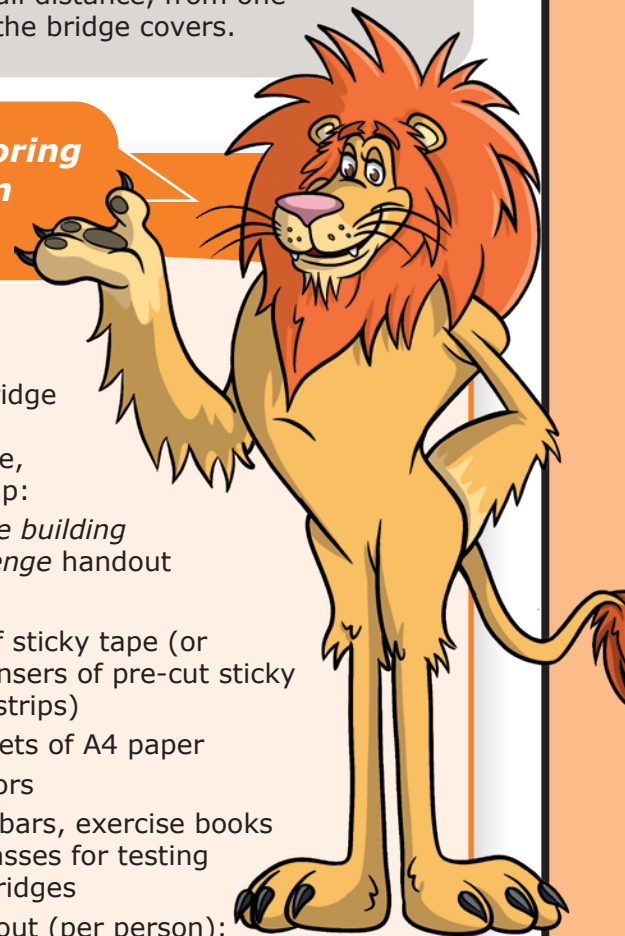
You will need...

- Ruler Beam bridge
 - Metre ruler
 - Books – enough to create two stacks/abutments, alternatively two desks that can be moved apart would work.
- Exploring beam bridges, per group:
 - Wooden building blocks (4 per group)
 - Strips of thin card (3 per group)
 - Masses (such as coins or washers, multiple per group)
- Handout: *Forces in a beam bridge*
- Large sponge (such as used for car cleaning), marked along the side with a marker pen, with vertical lines, approximately 2.5cm apart



We will start exploring forces and loads in beam bridges.

- Paper bridge building challenge, per group:
 - *Bridge building challenge* handout
 - Ruler
 - 1m of sticky tape (or dispensers of pre-cut sticky tape strips)
 - 6 sheets of A4 paper
 - Scissors
 - Mars bars, exercise books or masses for testing the bridges
 - Handout (per person): *Bridge building challenge certificate*





Something to Try:

What do you notice?



RULER BEAM BRIDGE

Create a beam bridge by resting a metre ruler on two stacks of books or between two desks. Keep the gap relatively small to begin with (20cm or so). Then test the bridge by gently pushing down on the middle. Ask learners what they notice. Ask learners what they think would happen if more force/load is added.

Pull the stacks of books/desks slightly further apart, increasing the span of the bridge, and repeat the test. What do the learners notice this time?

Repeat several times, increasing the span of the bridge slightly each time. What happens?



EXPLORING BEAM BRIDGES

Each team needs to be given 4 large building blocks, 3 strips of card, and some small masses (coins, washers for example).

They can then explore which type of bridge is the strongest: which bridge holds the greatest mass.

Some options for this might be:



A simple beam bridge, with 2 blocks at either end.



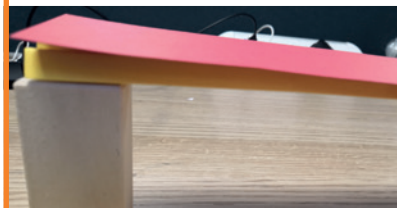
A beam bridge with reinforcement.



Or an arch support.



A beam bridge with an additional pier.



Encourage learners to explore all the different combinations of supports and card uses, testing them as they go. You could get each group to demonstrate their strongest bridge design and ask them to explain why they think it was the strongest.

Learners are encouraged to make scientific observations and to think about how to set up comparative and fair tests. They can then use scientific language to describe their observations.





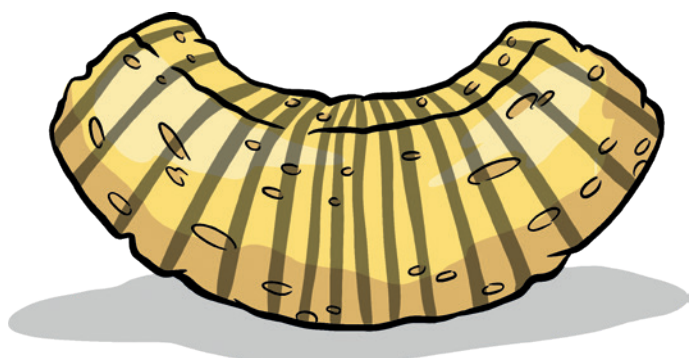
FORCES IN A BEAM BRIDGE:

Place two tables or desks about 40 centimetres apart and place a sheet of A3 card across the gap to make a simple beam bridge. Place a toy car in the centre to act as the live load. Ask the learners whether there is any tension in the beam bridge. If so, where is it coming from?



The forces in a beam bridge can be demonstrated visually using a large sponge, marked along the sides.

Take the sponge with vertical lines on. Bend it like a beam bridge carrying a heavy live load.



Observe that the lines at the top are closer together – so what is the force?

Compression.

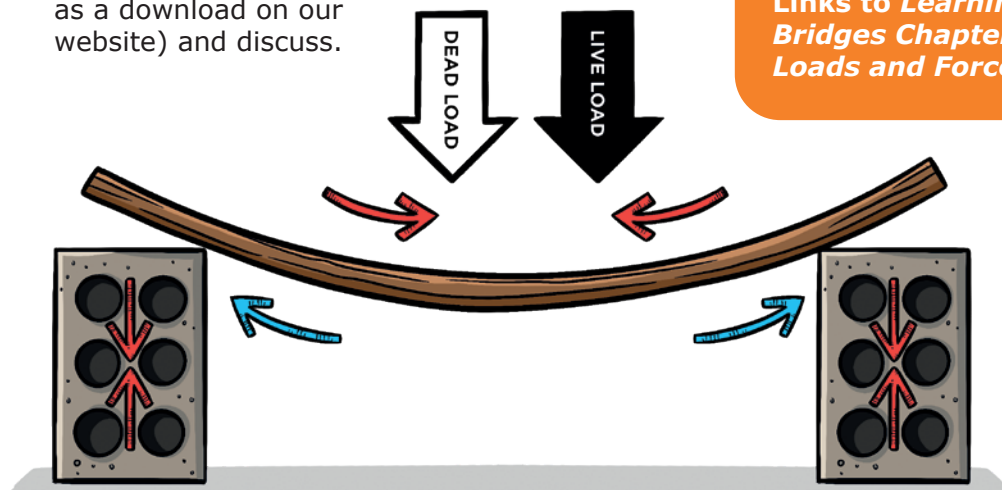
Observe that the lines at the bottom get further apart – so what is the force?

Tension.

So there is tension in the beam of a beam bridge.

When a force is applied from above, the top of the sponge shows compression and the bottom of the sponge shows tension.

Look at *Forces in a beam bridge* handout (available as a download on our website) and discuss.



Links to Learning About Bridges Chapter Aii: Loads and Forces

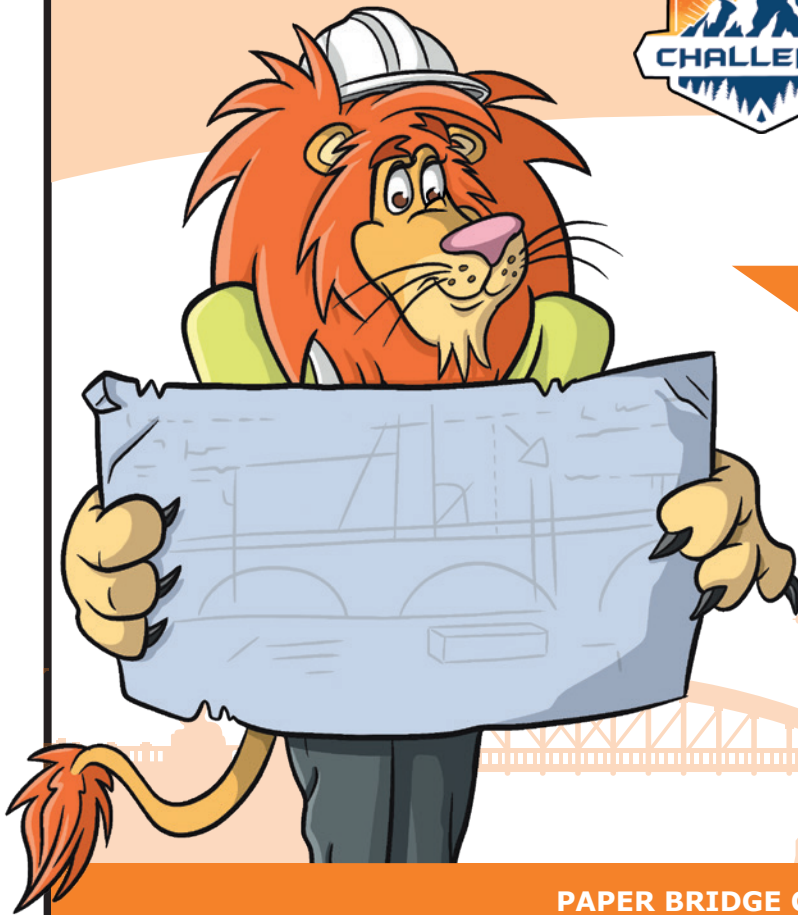


Given what has been explored in this section (and the previous chapters), discuss how an engineer might try to cope with these forces to make a beam bridge really strong.

The forces in a beam bridge.



Challenge Time!



What is the strongest bridge you can create with paper and sticky tape? Will you receive my certificate of bridge building mastery?



PAPER BRIDGE CHALLENGE

For your convenience, there is an illustrated step-by-step guide on the following pages.

1. Set up a testing zone by placing two chairs or tables 40cm apart.
2. Divide the learners into small groups of 2-3 people, if possible. Each group needs a ruler, 1 metre of sticky tape, 6 sheets of A4 paper, scissors and a *Bridge building challenge* handout. No other materials should be used, but you may wish to provide some pens/pencils and paper to help the groups design and test their initial ideas. Instead of 1 metre of sticky tape, you may find it more convenient to use dispensers of pre-cut sticky tape strips.
3. Give the groups a short time (10 minutes) to discuss and plan how they are going to make their bridge the strongest.
4. The groups then have 30 minutes to build the strongest bridge they can. Do not give the learners any guidance at this stage; let them explore the possibilities for themselves.
5. When the time is up, invite each team to bring their bridge to the testing zone. Load the bridges up with Mars Bars/exercise books/masses. When the bridge collapses, count the number of items it was carrying just before it fell (i.e. do not count the last one).
6. Record the scores for comparison. Ask the learners to observe the way the bridge failed: it is important that learners consider the weaknesses of their bridges. Encourage them to think of solutions to how they could be improved. Did it fold? At which part? What could be done to reinforce that point?



Links to Learning About Bridges Chapter Aii: Loads and Forces and Chapter Bi: Beam Bridges – The First Bridge



7. After the learners' first attempts have been tested and discussed, you can then lead them, step-by-step, through one possible solution which gives a good result. See the following pages for an example solution, either using the resources or by hand. Reinforce that this is not the only solution; learners should try to apply what they have learnt rather than entirely copying the example.
8. Give the teams 3 more sheets of paper and a very short time (5 to 10 minutes) to make modifications and test them again to see if they can better their scores. This is important as learning from experience is an important engineering process.
9. The winning team is the one whose bridge holds the highest number of items.
10. Certificates available in the Handouts pack at www.rochesterbridgetrust.org.uk can be printed and presented to participants.

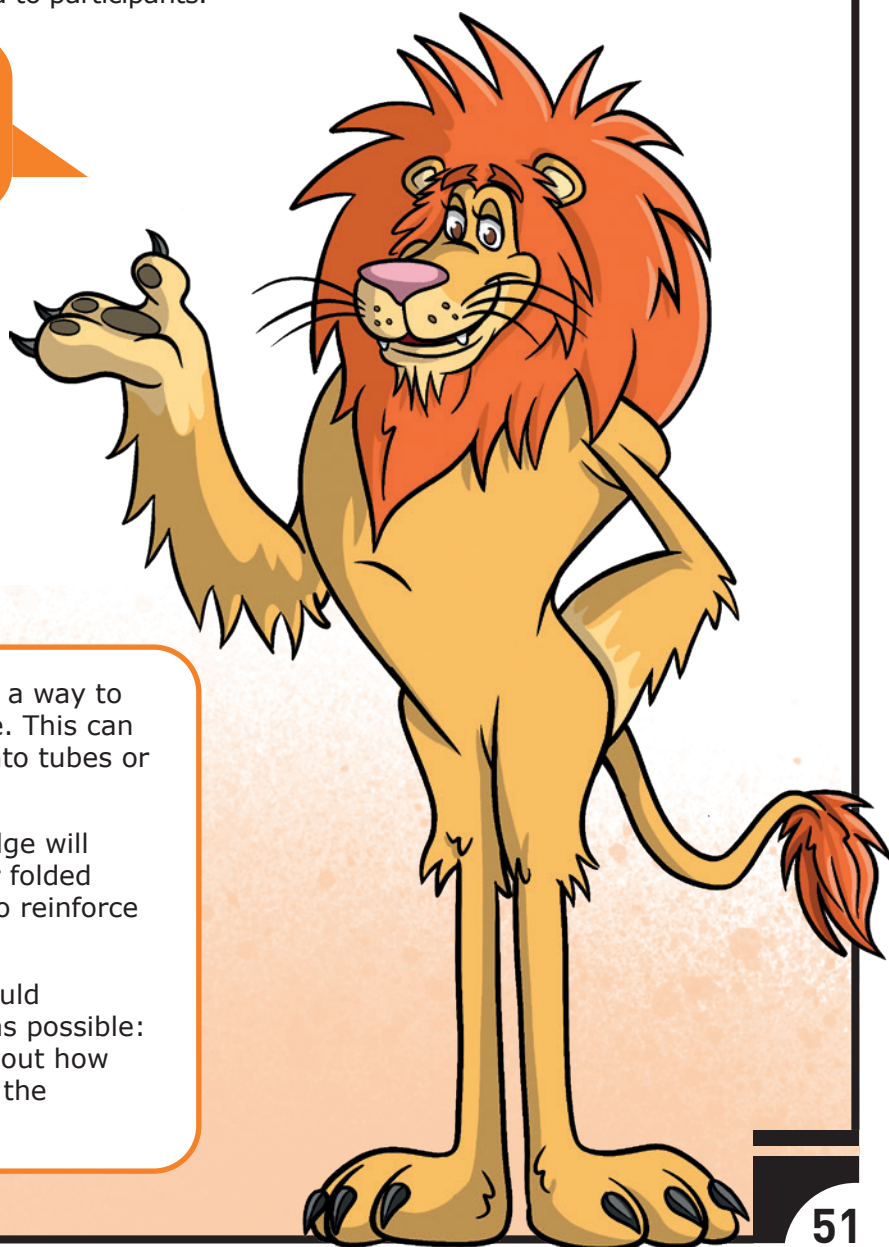
Here are some hints and tips to help with the challenge.



The key to this challenge is to find a way to make the paper as stiff as possible. This can be achieved by rolling the paper into tubes or folding into a concertina.

The weakest part of the paper bridge will be the joints between the tubes or folded sections. Encourage the learners to reinforce the joints as much as possible.

Every part of the paper bridge should contribute to making it as strong as possible: encourage the learners to think about how each piece of paper contributes to the strength of the bridge.





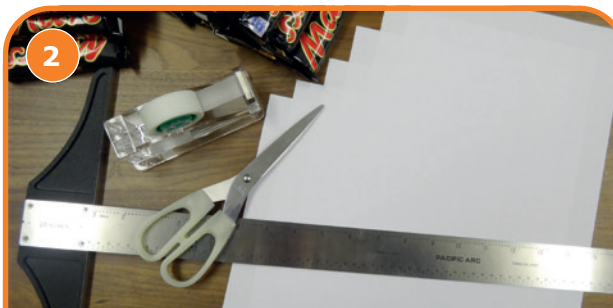
A STEP-BY-STEP SOLUTION FOR THE BRIDGE BUILDING CHALLENGE

1



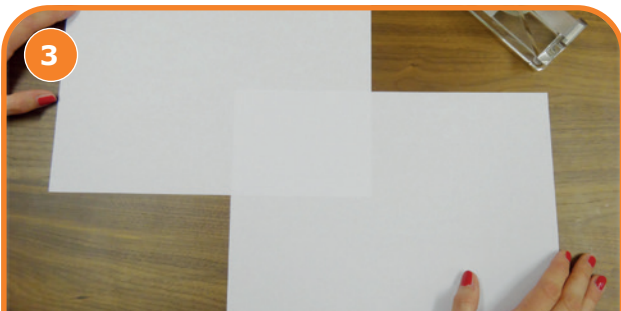
Set up a testing zone by placing two chairs or tables 40cm apart.

2



Materials: 6 sheets of A4 paper, 1 metre of tape, scissors and a ruler.

3



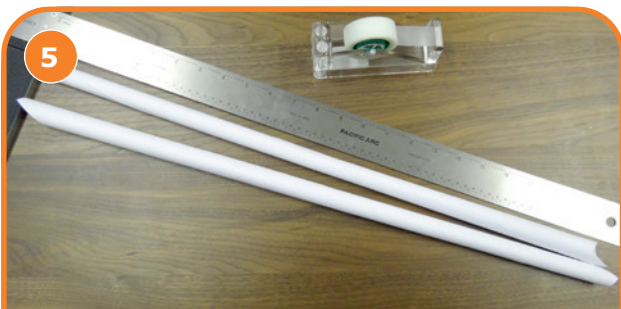
To make two beams: Place 2 sheets of paper over each other so the corners overlap.

4



Roll the sheets into each other, ensuring that the total length of the tube is 55cm.

5



Repeat the process to make 2 tubes (beams) which are each 55cm in length.

6



Bend each beam approximately 5cm from each end.

7



Tuck the ends of one beam into the ends of the other beam. Tape together.

8



The result is a rectangle made of your beams.



A STEP-BY-STEP SOLUTION FOR THE BRIDGE BUILDING CHALLENGE

9



Take the remaining 2 sheets of paper and cut in half lengthwise.

10



Set aside 1 strip to use as the deck; the other 3 strips will be used for secondary beams.

11



Make 3 secondary beams: Roll up each strip to make a tube. Tape to secure each beam.

12



Fold one beam in half; leave the other 2 beams straight.

13



Attach the secondary beams to the main beam and secure with tape.

14



Attach the secondary beams to the main beam and secure with tape.

15



Attach the secondary beams to the main beam and secure with tape.

16



Your beam is almost ready!



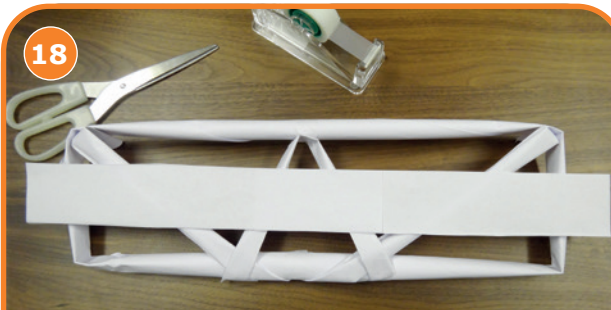
A STEP-BY-STEP SOLUTION FOR THE BRIDGE BUILDING CHALLENGE

17



Find the strip that set you aside in Step 10 and cut it lengthwise. It's going to be the deck.

18



Tape the strip to the beam.

19



Now it's time to test your bridge! Place it in your testing zone.

20



Load your bridge with Mars Bars (or other masses), placing them evenly on your deck.

21



See how many Mars Bars you can put onto your bridge before it collapses.

22



When it collapses, you can see the weak points and make adjustments by adding more tape.

23



Make adjustments and then try again. See if you can build a stronger bridge!

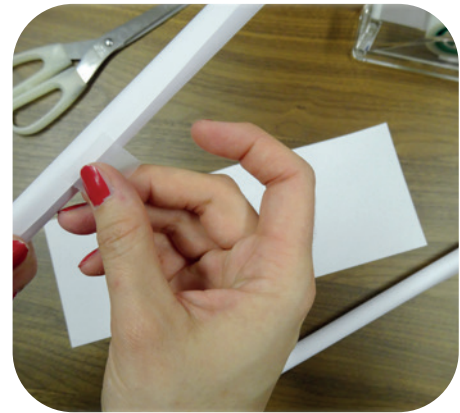




Why are circular tubes so strong?

Tubes are strong because they are difficult to bend. Try folding one piece of A4 paper like a fan and rolling another piece of A4 paper into a tube. Which one is more difficult to bend?

The rolled piece of paper is much more difficult to bend. This is because tubes have both rigidity and depth. As you increase the diameter of the tube it gets weaker/easier to bend. This is because the paper becomes less curved or flatter and the number of layers of paper decreases.

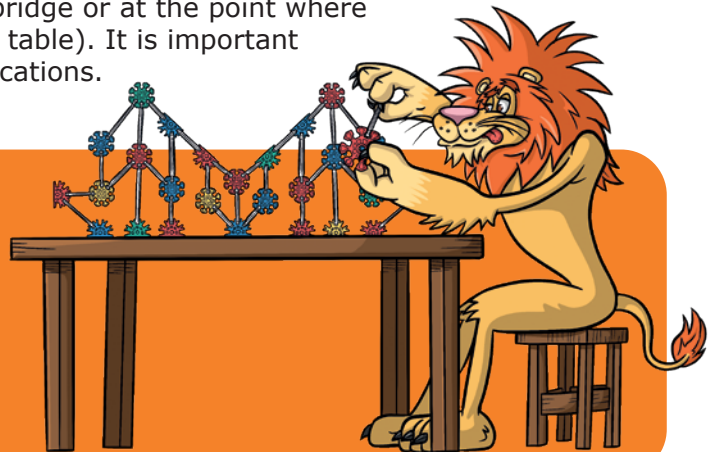


Why is the type and location of each connection important?

Connections are often the weakest point in a bridge. The highest forces in a bridge are generally at the centre of the bridge or at the point where they meet the abutment (in this example, the table). It is important that weak connections are avoided at these locations.



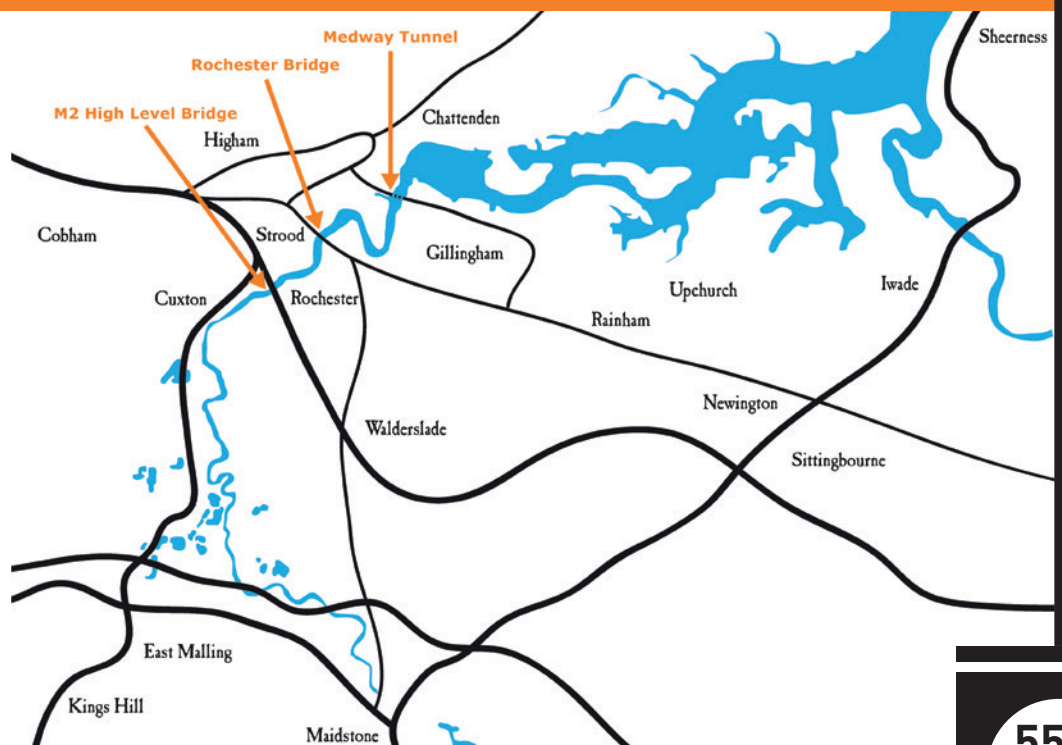
You could also try building a real life beam bridge in an outside space. If you can get a plank of wood, some old car tyres or bricks, you can demonstrate the simplest beam bridge. Ask learners to consider how they could make it more stable or safer in any way.



HOT TOPICS!

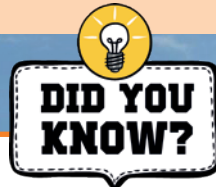
You could find out about the history of Rochester, including reasons why the town built up at this part of the River Medway.

Perhaps you could research a local town or area around a river near to you, if you live elsewhere.





Beam bridges are simple, but strong: they balance the loads and forces to stay standing. When you are in your local area, take a look at structures around you – it could be bridges, but perhaps they are tall buildings, tunnels or famous landmarks? Think about how the structures stay standing: what forces are acting on them, how do they balance those forces? Remember, forces are found in pairs.



The Guinness Book of World Records had to clarify their definition of 'world's longest bridge over water' in 2011, when the Jiaozhou Bay Bridge was opened, and China claimed that this was longer than the previous world record holder, the Lake Pontchartrain Causeway in southern Louisiana. The organisation decided to split the title into separate categories: the world's longest continuous bridge over water, and the world's longest aggregate bridge over water – the Jiaozhou Bay Bridge is actually made up of land bridges and sea tunnels. The world's longest continuous bridge over water remains as the Lake Pontchartrain Causeway.

Lake Pontchartrain Causeway (Photo by Glenn from Houston, USA via Wikimedia)

WRONG WAY



Langdon presents:

- *Forces in a beam bridge* handout
- *Bridge building challenge* handout
- *Bridge building challenge* certificate

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