Chapter Lii: Cantilever Bridges – The Tay Bridge Disaster

AIMS & OBJECTIVES

- To recognise some key features of cantilever bridges
- To apply a historical context to engineering
- To understand how environmental factors can play a role in engineering

CONTEXT

Cantilever bridges can span long distances, often over water, whilst carrying heavy loads. The Forth of Tay disaster is hugely significant in the development of bridge engineering, specifically cantilever bridges. In order to understand why cantilever bridges were needed, and indeed why we have a cantilever Forth Bridge at all, it is necessary to appreciate the events that happened in the recent history of the region.

LANGUAGE OF BRIDGES:

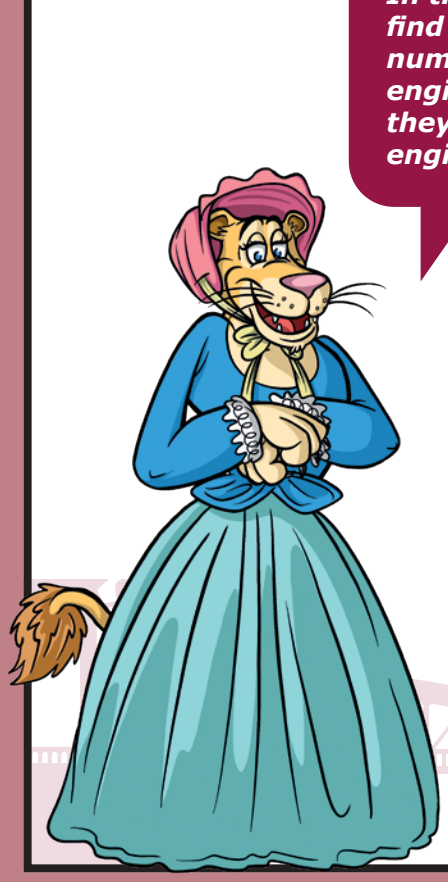
Cantilever: A horizontal structure that projects into space at right angles (perpendicularly) to its supporting structure, supported or fixed at only one end.

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

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

You will need...

- Handout: *Spot the cantilever!*
- Resource: *Spot the cantilever!*
- Handout: *Tay and Forth rivers map*
- Handout: *Social Media Post*
- Per group:
  - Packet of spaghetti
  - Sticky tape, such as Washi paper tape or colourful electrical tape



In this session we will find out more about a number of Victorian engineers and how they changed bridge engineering!

Queen Victoria once said 'We will not have failure – we will have success and new learning': it may not have been that easy!

Something to Try:

Which ones are cantilevers?

Give groups copies of the various bridge images from the *Spot the cantilever!* resource and/or handout. Ask learners to see if they can identify which bridges are cantilevers and the common features of cantilever bridges.

BRIDGING THE RIVER TAY:

At the start of the Victorian era, there were few railway lines built in Scotland. Ask learners why they think this might have been a problem for people living in Scotland during this period.

Railway companies were eager to build more and more railway lines, to allow people and products to be moved across the country, following the industrial revolution. To compete with rail lines built from Glasgow that dominated north of the Tay, the North British Railway Company decided to bridge both the Tay and the Forth.

Show learners the Tay and Forth rivers map resource, showing the area around the River Tay (Firth of Tay). Ask them why a bridge might be useful.

This links back to Do we need bridges chapter in *Learning About Bridges Vol 1*.

Ask the learners to consider why a railway bridge might be more useful than a road or foot bridge, for example: they should consider it was during the Victorian era, after the Industrial revolution.

You might ask them to consider what type of bridge they might build, and where exactly, across the Tay they would build it. They might consider the span of the bridge required, depth/speed of the river flowing beneath it, where the bridge is more needed by the local population, for example.

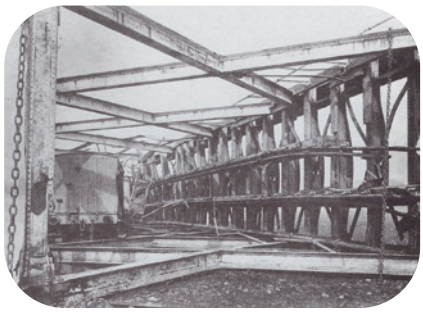
Sir Thomas Bouch

Sir Thomas Bouch was born on 25 February 1822. He became a well-known and renowned British engineer who developed the first roll-on/roll-off rail ferry (across the Forth). This saved railway companies lots of time as they didn't need to unload and reload the train carriages when the train arrived at the river, they could transfer the carriages to the ferry directly.

Bouch was highly regarded for his work on railways, using a lattice girder design for a number of bridges he designed. He was selected as engineer to cross the Tay and Forth rivers.

Bouch used his trusted lattice girder design and as shown in the photo, the lattice girders ran underneath the railway track, and then the track ran through the girders when the height of the bridge had to be raised in the centre, to allow ships to pass.

Photo from the National Library of Scotland via Wikimedia Commons



Photos from the National Library of Scotland via Wikimedia Commons

The bridge was supported on a total of 85 piers – the first 14 of which are brick and masonry, and although it was intended that the remaining piers be built in the same construction method, it was found that the bedrock was too deep (despite surveys that suggested the contrary), finding only gravel, and as such the piers were instead cast-iron columns braced with wrought iron struts and ties, mounted on a concrete base, so as to reduce the mass of the structure supported. The number of piers was also reduced, and the span between them in the central sections therefore increased. The bridge was opened on the 1st June 1878.

An internet search for Tay bridge disaster should produce some short Open University videos that explain what took place in the evening of 28th December 1879, only 6 months after the bridge was opened.

This is an illustration by an unknown author showing the search for passengers on the train.

The photographs are originals taken in 1879: apparently the images are incredibly high resolution, particularly notable for the time.

Various sources suggest the bridge was still there as the train approached, and it was the train on the bridge that caused the bridge to fail.

LITERACY

Using the *Social Media Post* Handout, challenge learners to write a post to explain the disaster as if the learners were there. What would they say? What do they think the response would be from people on social media if this happened now?

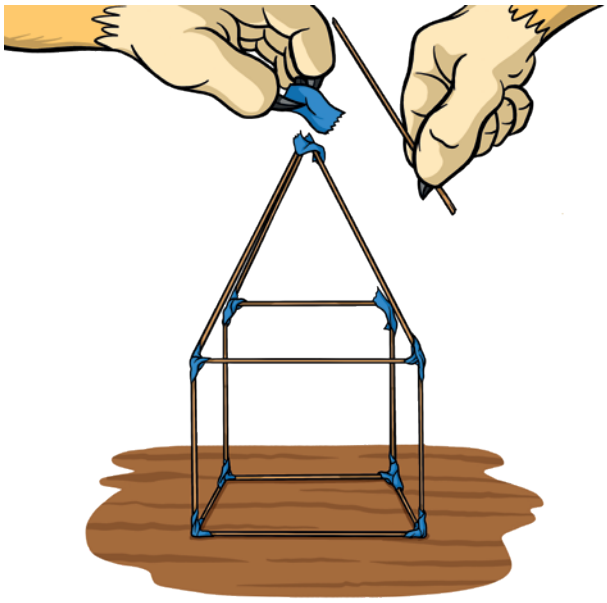
Challenge Time!

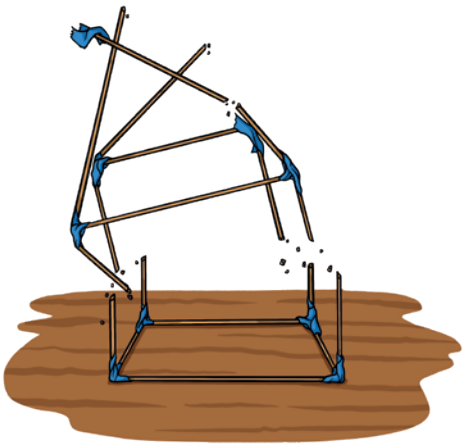
CHALLENGE

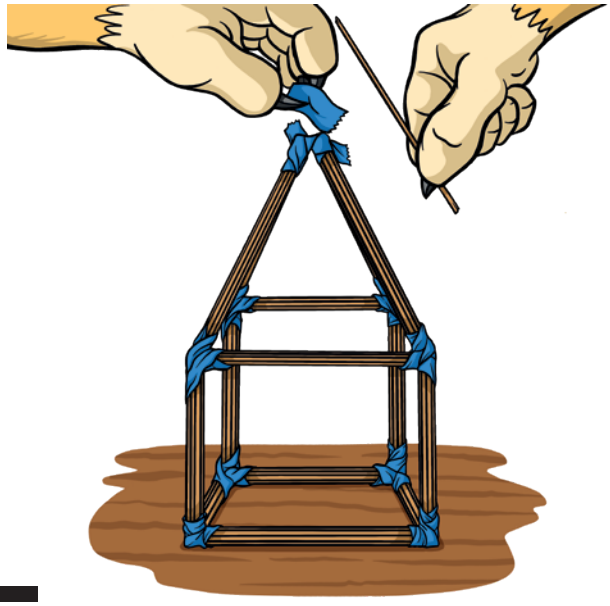
BOUCH'S TAY BRIDGE

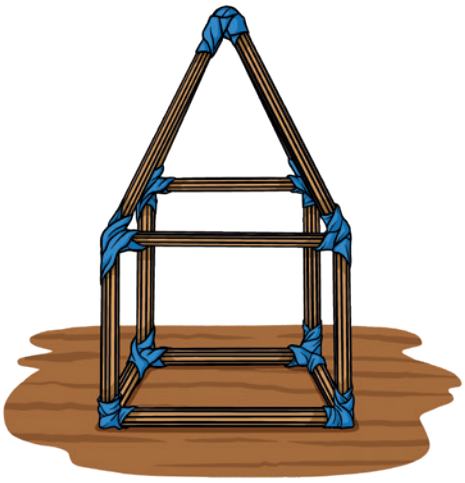
Cast iron is a brittle material no longer used in modern constructions. Challenge learners to build a pier like those of Bouch's using just spaghetti and tape. Ask them to explore how tall and narrow they can make their towers. You can then test them to destruction! Learners will no doubt find spaghetti a very brittle difficult material to work with, and find it challenging to construct a strong, tall tower from.

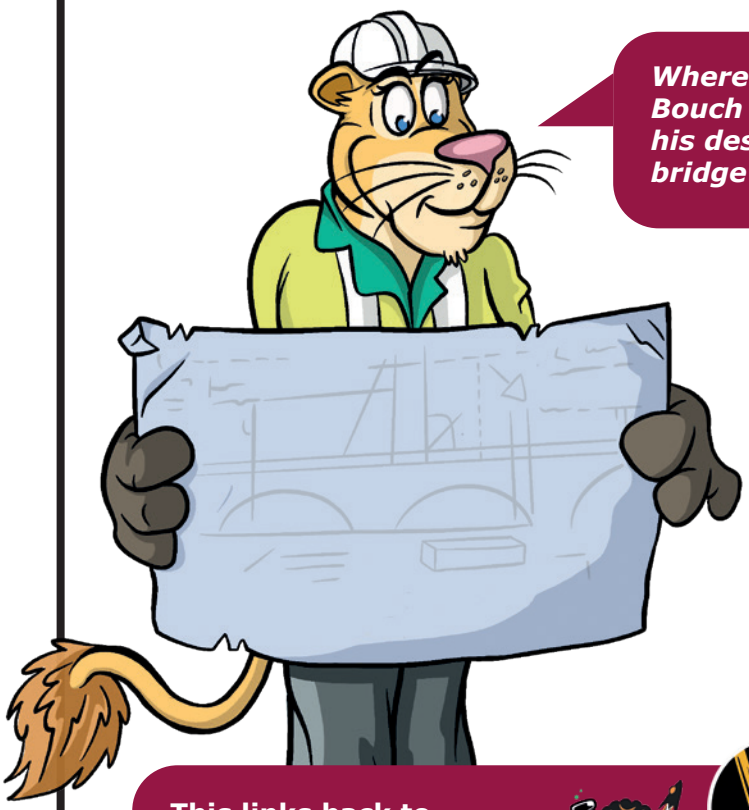
THINK LIKE AN ENGINEER











Where did Sir Thomas Bouch go wrong with his design for the bridge over the Tay?

Where did Thomas Bouch go wrong?

The following information is a summary of numerous sources and a number of the suggested reasons for the failure.

The Court of Inquiry found that Bouch's design was insufficient to withstand the wind – there were too few cross-bracings or fastenings.

It has been estimated that the gale that came in late that evening was a force 11. The bridge design had not been tested at such wind speeds.

Under such winds, the types of materials used also become a factor. It seems that cast iron bolts, not expected to be under tension in the structure, may have been under tension due to the movement of the bridge due to the high winds. If the cast iron bolts had been made of wrought iron, they would have been more able to withstand the forces caused by the loads on the bridge.

This links back to the Loads and Forces chapter in *Learning About Bridges Vol 1*.

Additionally, the design of the columns was altered to make them easier to build, making the fixings slightly weaker than usual. Therefore, as the wind, rain and loads of the trains acted on the bridge, the fixings couldn't withstand the forces. Photographs suggest that the cast iron column piers broke at these points.

Bouch had the reputation of building 'modestly priced' bridges and probably was under pressure, from this and his clients, to continue building the bridge cheaply, making decisions that kept the cost low but also may have weakened the bridge. This may have led to a rather hasty, poor quality build; girders which had accidentally been dropped into the (salt) water beneath were re-used, rather than replaced, the cast iron itself may have been of poor quality and joints poorly completed.

Additionally, the larger Edinburgh locomotive may have contributed to the bridge failure. An earlier train that was a smaller load on the bridge, with the same winds, had been seen to produce sparks as it crossed: these sparks are thought to be from the iron wheels rubbing against the lee (sheltered) side of the track as the train has been pushed over slightly. A larger train would have added a greater load to a weakened bridge, as well as provided greater resistance to the wind.

The fact that the initial surveys had been wrong about the depth of the bedrock, leading to the central piers being redesigned, may have also contributed to the weakness, and therefore reduced the load that the bridge could carry.

A worker maintaining the bridge had also given testimony to the Inquiry that a number of the ties had been working loose. Whether this was due to the design of the tie fixings alone (as mentioned earlier) or by the fact that the wind and/or movement of the train across the bridge had worked it loose, isn't known. However, it is clear that he carried out repair work by hammering small lengths of iron into the holes to ensure that the fastenings were tightened.

HOT TOPICS!

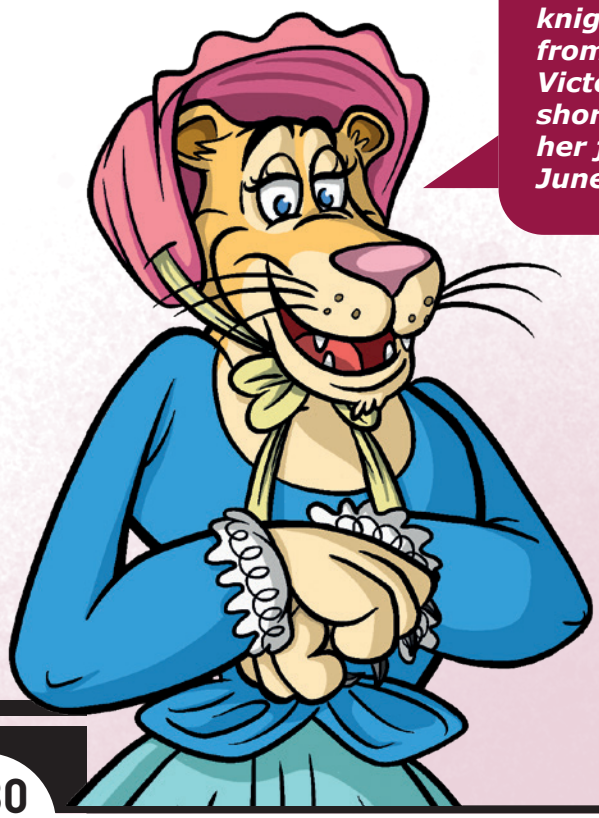
Leaners could write newspaper articles or present a news report on a factual or fictional bridge disaster.

Learners could research more about the industrial revolution and find out why more railway lines, canals and indeed bridges, needed to be built as a result.

You could try writing a poem about the Tay Bridge Disaster. William McGonagall, dubbed Scotland's 'best worst poet' wrote a poem about the Tay Bridge Disaster (if you search online, you may be able to find the poem itself and more information about William McGonagall himself).

Can you find out about any other accidents that have happened with bridges? What has happened to the bridge, why and when? It might be that a local bridge has been washed away in a flood, or had a vehicle drive into it…

There are some well-known bridges that are always getting crashed into on the internet – in fact, there is a bridge famous for the way trucks are always crashing into it because it is only 11ft 8 tall (about 3.5m tall, so a double decker bus is taller…) and videos appear on YouTube often (search for '11foot8 bridge' to find out more).



Thomas Bouch received his knighthood from Queen Victoria shortly after her journey in June 1879.

DID YOU KNOW?

Queen Victoria crossed the Tay Bridge just a year after it was opened, on her way south from Balmoral. Not long after that, in December 1879, it collapsed.

Langdon presents:

- *Spot the cantilever!* handout
- *Spot the cantilever!* resource
- *Tay and Forth rivers map* handout
- *Social Media Post* handout

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