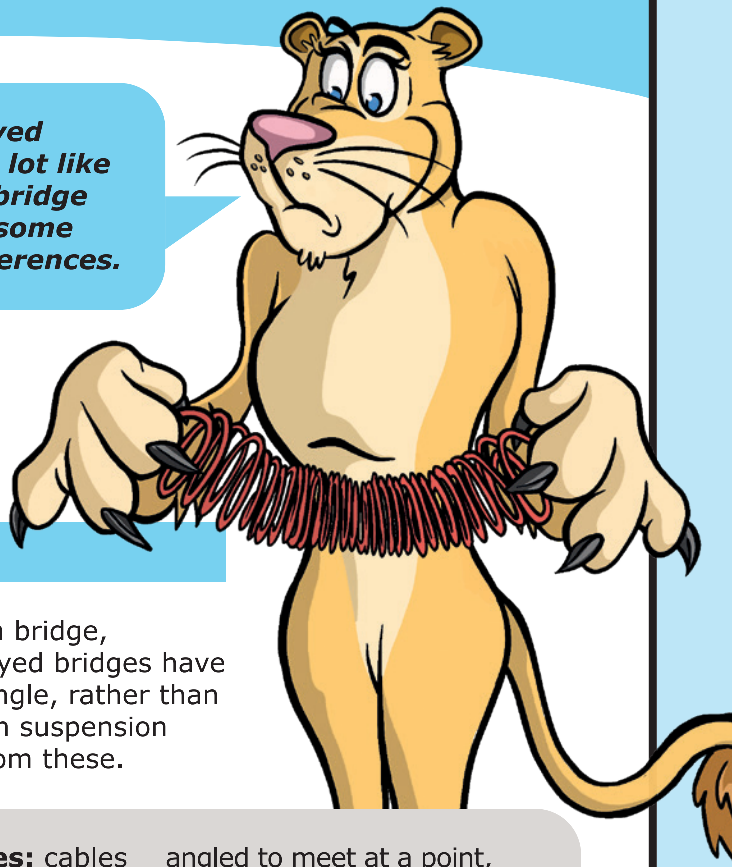
Chapter J: Cable-Stayed Bridges

AIMS & OBJECTIVES

- To introduce the cable-stayed bridge
- To appreciate the differences and similarities between cable-stayed and suspension bridges
- To understand how cable-stayed bridges can be used with beam spans to make very long bridges



CONTEXT

The cable-stayed bridge looks a lot like a suspension bridge, but there are some important differences. Cable-stayed bridges have cables attached to towers or pylons directly, at an angle, rather than the main cable going over the top of the towers as in suspension bridges, where secondary cables then hang down from these.

LANGUAGE OF BRIDGES:

Anchor: acts to secure the bridge to the ground.

A-Shaped Pylon: pylon that looks like the letter A when viewed from the end of the bridge, as it has two upright members that meet at the top.

Cable-stayed bridge: bridge where the cables attach directly to the towers or pylons at an angle.

Column Pylon: single vertical pylon.

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

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

Fan shaped cables: cables that are attached to the pylon at the same point, or very nearly, but attach at further intervals on the deck, creating a triangular shape that resembles a traditional hand-fan.

H-Shaped Pylon: pylon that looks like the letter H when viewed from the end of the bridge, as it has two upright members and a horizontal member between them.

Harp shaped cables: cables that are attached to the pylon and the deck at regular intervals, so they run parallel to each other.

Inverse Y Shaped Pylon: pylon that looks like the letter Y upside down, when viewed from the end of the bridge, as it has two upright members angled to meet at a point, and continues vertically up as a single column.

Piers: the upright columns that support the bridge.

Pylon: the tower or vertical part of the bridge to which the cables are attached.

Span: the distance between bridge supports.

Suspension bridge: bridge in which the deck is hung from main cables on vertical hangers.

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

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

You will need...

- Handout: *Comparing Cable-stayed and Suspension bridges*
- Handout: *Cable-stayed bridge examples*
- Handout: *Cable-stayed bridge terminology*
- Handout: *Describing cable-stayed bridges 1 – pylons*
- Handout: *Describing cable-stayed bridges 2 – cables*
- Handout: *Name the cable-stayed bridge*
- Forces in a cable-stay bridge demo:
  - Two shopping bags
  - Various lightweight items to put in the bags – the load should be noticeable but not excessive
- Exploring cables:
  - Lengths of string

Something to Try:

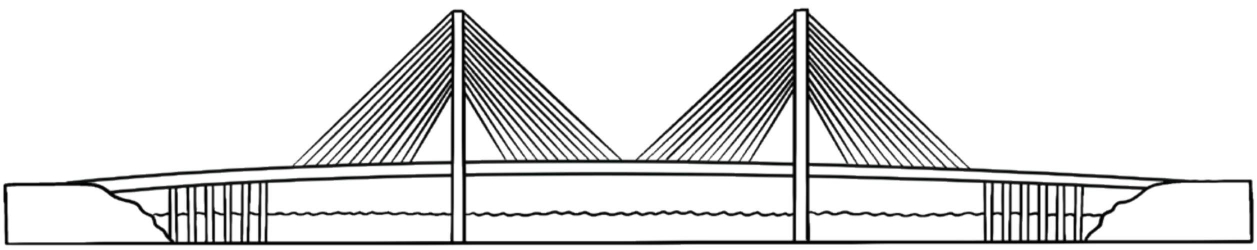
What's the difference between a suspension bridge and a cable-stayed bridge?

Links to *Learning About Bridges Vol 1 Chapter Ei: Suspension Bridges – Hanging Tough*

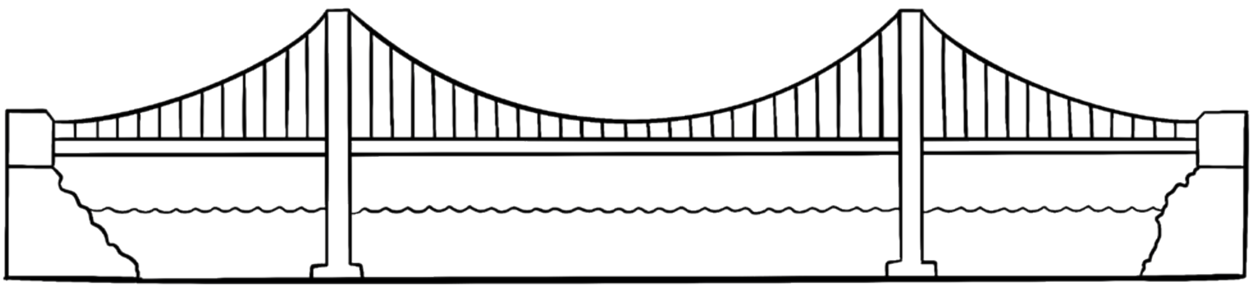
In the section on suspension bridges in book 1, there were a number of activities that demonstrated how suspension bridges are able to bridge wide gaps, and why they need to be well anchored to support the load.

Ask learners to compare the two designs and notice the differences and similarities.

Learners might notice that the cables are attached to the towers or pylons in different ways – in a cable-stayed bridge the cables attach directly to the tower at an angle; in a suspension bridge, the main cable runs over the top of the tower, with the secondary cables, or hangers, hanging vertically from the main cable.



Cable-stayed bridge



Suspension bridge

HERE ARE SOME EXAMPLES OF CABLE-STAYED BRIDGES

Clockwise from top left:

Prince of Wales Bridge, River Severn near Bristol, UK. Photo by mfjordan via Wikimedia;

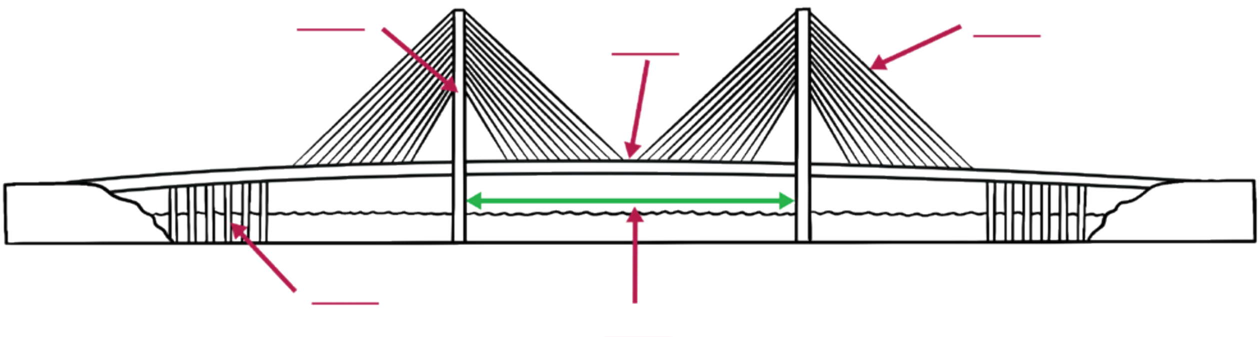
Los Fundadores Bridge, Envigado, Colombia. Photo by chilangoco via Wikimedia;

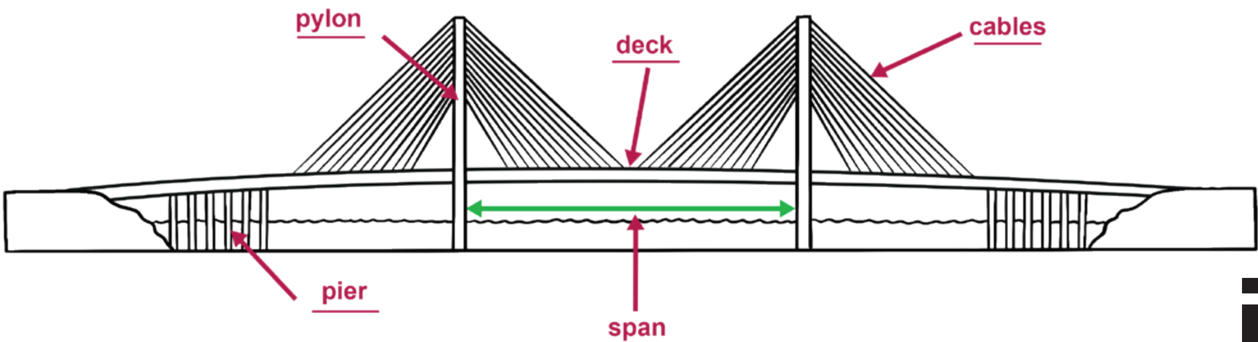
Anzac Bridge, Sydney, Australia. Photo by Adam J.W.C via Wikimedia;

Zakim Bridge, Boston Massachusetts, USA. Photo courtesy of the Boston Airport Express via Wikimedia

THE LANGUAGE OF BRIDGES

Give learners a copy of Cable-stayed bridge terminology handout, and ask them to try to label the different parts of the bridge. Some of the words they might already be familiar with from other bridges, but perhaps not all.

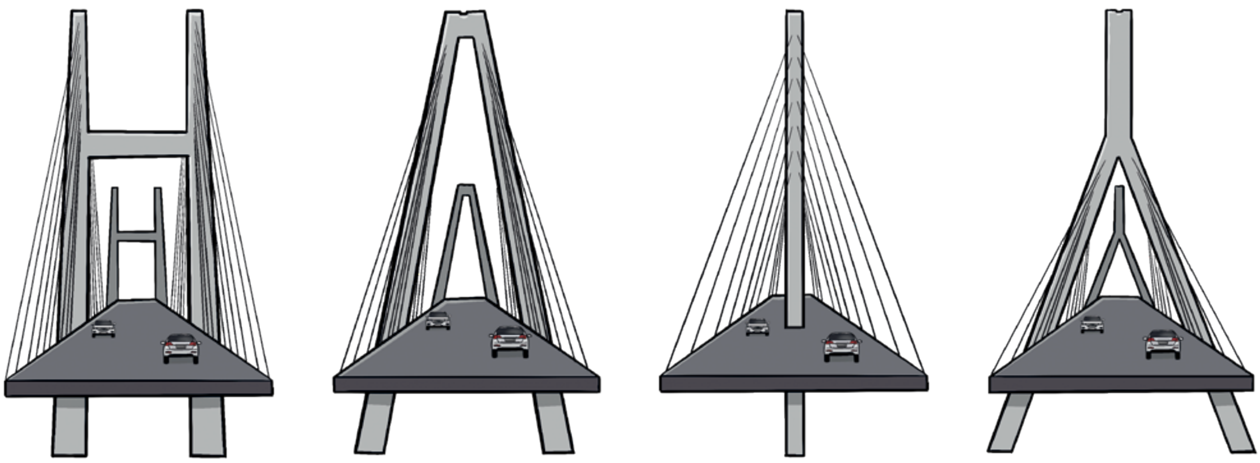


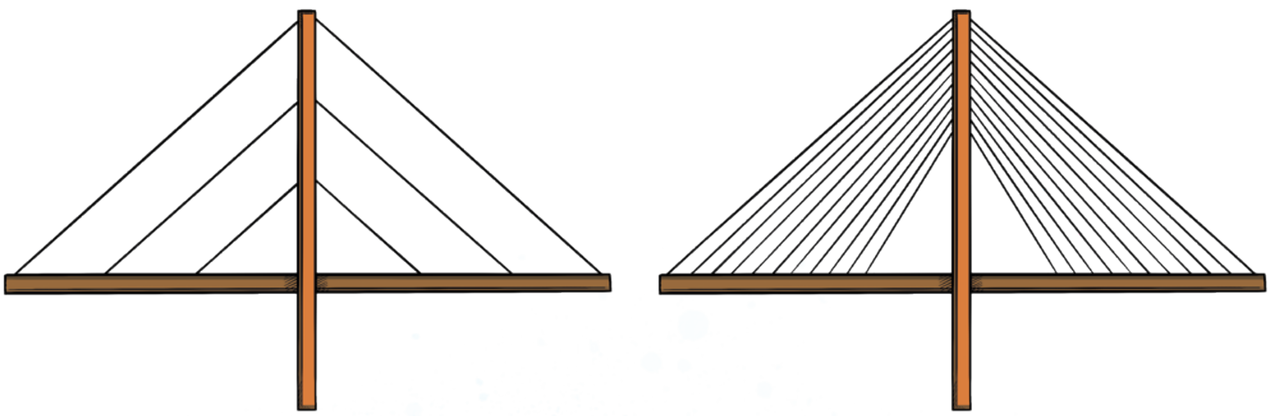


Cable-stayed bridges are described by:

- The number of pylons they have
- The shape of the pylons, and
- The arrangement of the cables.

The following diagrams show the different shapes of pylons and arrangements of cables. Ask learners to try to explain why each shape has the name it has. The handouts *Describing cable-stayed bridges 1 – pylons*, and *Describing cable-stayed bridges 2 – cables* show these diagrams.





In addition to the images here, learners could search on the internet for images of the following bridges and try to identify and name the different features of the bridges using the correct terminology.

- Stonecutters Bridge
- Pont de Normandie
- Jingyue Yangtze River Bridge
- Øresund Bridge
- Helgeland Bridge
- Can Tho Bridge
- Queen Elizabeth II Bridge

You could alternatively use the handout *Name the cable-stayed bridge*.

WHY BUILD CABLE-STAYED BRIDGES?

Although they are expensive, cable-stayed bridges are easier and cheaper to build than suspension bridges. They have stiffer decks so don’t tend to bounce and sway in the wind as much as suspension bridges. They can be built where the ground on each side is not as suitable for constructing large anchor blocks.

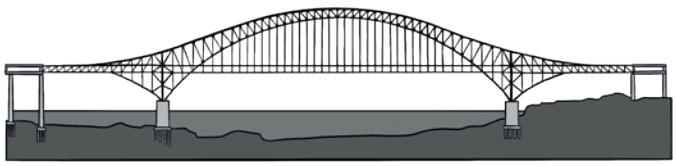
Carry out an internet search for the National Geographic documentary Impossible Bridges: Denmark to Sweden (some sections are on YouTube) – in this video, engineers are deciding between the main types of bridge for a new crossing between Denmark and Sweden.

Cable-stayed bridges can’t be as long as suspension bridges. The maximum span is about 1,100 metres (compared to 2000 metres for a suspension bridge). The Russky Bridge in Vladivostock, Russia has the longest cable-stayed span in the world at 1,104m metres. Remember this is the distance between the towers not the total length of the bridge.

The longest bridge over water in the world is the Jiaozhou Bay bridge in China which opened in 2011. The main span is a cable-stayed bridge. The total length of the bridge is about 42.3kilometres – long enough to run a full marathon on – and it could span the English Channel at its narrowest point, with about six miles to spare. The bridge cost £1.4billion.

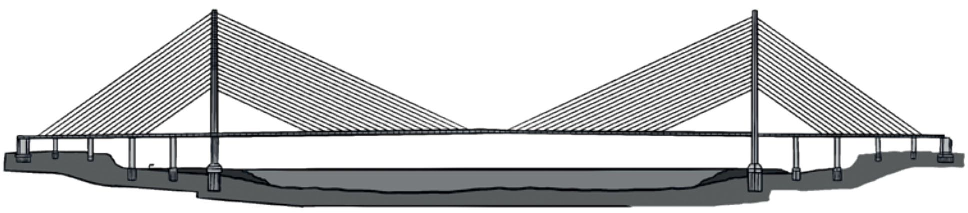
This compares the longest spans of the main bridge types:

Rio-Niteroi, Brazil (Beam) – 300m



Ciaotianmen, China (Arch) – 552m

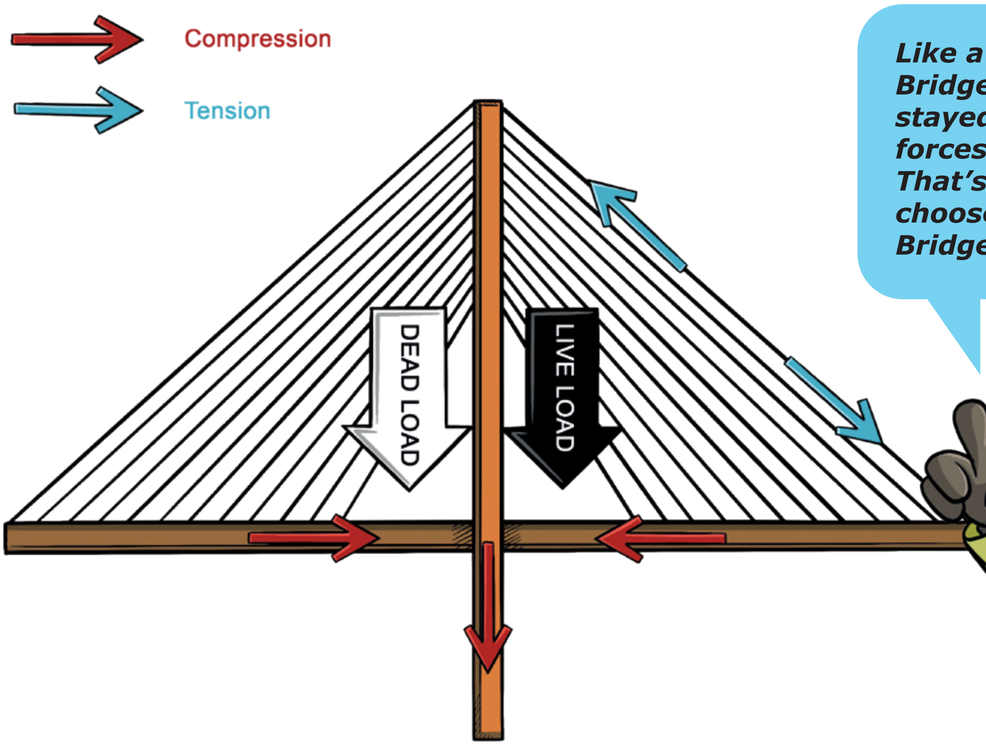
Akashi-Kaikyo, Japan (Suspension) – 1,991m



Russky, Vladivostock Russia (Cable-stayed) – 1,104m

UNDERSTANDING THE FORCES ON A CABLE-STAYED BRIDGE

This diagram shows how the forces in the cable-stayed bridge are transferred.



A really simple way of demonstrating how the forces change in the cables of the bridge is to use shopping bags. Ask the learners to hold two bags, containing some items, straight down and close to their body. Ask them to gradually lift their arms to the sides, at an angle away from the body, mimicking the way the cables move out away from the pylon on the bridge. Ask learners to describe what they notice.

As the bag moves further out/up, learners should report that the bag feels heavier (despite it not actually gaining any mass). This reflects the distribution of the forces in the cables of the bridge – the further the cable is from the pylon, the greater the force exerted.

EXPLORING CABLES

Cables are obviously key components of both suspension and cable-stay bridges.
Give learners lengths of string.
Ask them to split it down to the component fibres.

Ask learners to apply tension (remember this is a pulling force) and observe what happens. Encourage them to test their observations with one strand, two strands and so on. Discuss what they find. They should notice that each individual strand snaps easily when some tension is applied, however, even just 6 strands wound together becomes much stronger and "unsnappable". This is why the cables found in bridges are made of steel wires wound together to make strong steel cable, which are then wound together to make even stronger cables.

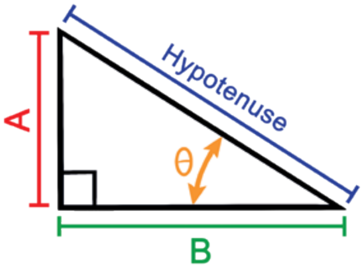
Challenge Time!

Build a cable-stayed bridge. You could construct a cable-stay bridge out of cardboard tubes, or use 6mm square section wood as often used in Design and Technology activities to create the pylon, and card for deck. Challenge learners to build a working bridge using one of the string arrangements detailed above, and test the bridge using small masses, such as coins or hex nuts. If they use the wood to construct the pylons, they may need to have assistance in creating holes with which to thread the cables.

Challenge learners to bridge a gap of 50cm – you should be able to demonstrate that the card bridge deck alone across the gap sags and cannot support a large load. Once learners have constructed a string-cable stayed bridge, they should be able to demonstrate that the load the bridge can withstand is larger.

HOT TOPICS!

The cables of a cable-stayed bridge form a series of triangles with the tower and the deck. You could use trigonometry and Pythagorus' theorem to calculate the length and angles of the various cables in the different configurations in the cable-stayed bridge.



Cable-stayed bridges are one way of bridging a gap using wires or cables – a zip wire is another way!

You could make your own zipline out of smooth string or thread, attaching one end to something very sturdy and the other end at least 60cm lower. Make sure nobody can walk into it by accident though! Then you can design and build a container to transport something, like a small toy, Lego® or action figure, down the zip wire. You can then investigate how heavy you could make the carrier, or whether you can make the journey faster or slower.

When you are outside in your local area, or even further afield, look out for cables that help make structures stronger or more stable. These could be guy-lines on a tent, a temporary flag pole that you might see at a Scout camp, or even securing a telecommunications mast.

DID YOU KNOW?

The Millau Viaduct is a cable-stayed bridge across the gorge valley of the river Tarn in France. The bridge currently holds the world record for the tallest bridge. The deck is so high that sometimes it appears to be in the clouds!

There was a documentary about this particular bridge – in the World's Greatest Bridges documentary for Channel 5, Rob Bell explores the design and construction of the bridge. This can be found on the Daily Motion website.

Langdon presents:

- *Comparing Cable-stayed and Suspension bridges* handout
- *Cable-stayed bridge examples* handout
- *Cable-stayed bridge terminology* handout
- *Describing cable-stayed bridges 1 – pylons* handout
- *Describing cable-stayed bridges 2 – cables* handout
- *Name the cable-stayed bridge* handout

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