Chapter Aiv: Working with Water

AIMS & OBJECTIVES

- To learn about some of the techniques civil engineers use for building structures under water
- To consider some of the challenges faced by civil engineers when designing bridges

CONTEXT

Most bridges will require some sort of building in water, whether that is developing the abutments or constructing piers to support the deck. The longer or bigger the bridge, the more complex this will be. The Romans were the first to build a bridge at Rochester, in 43AD, because they were the first to have the technical skills to be able to do so.

LANGUAGE OF BRIDGES:

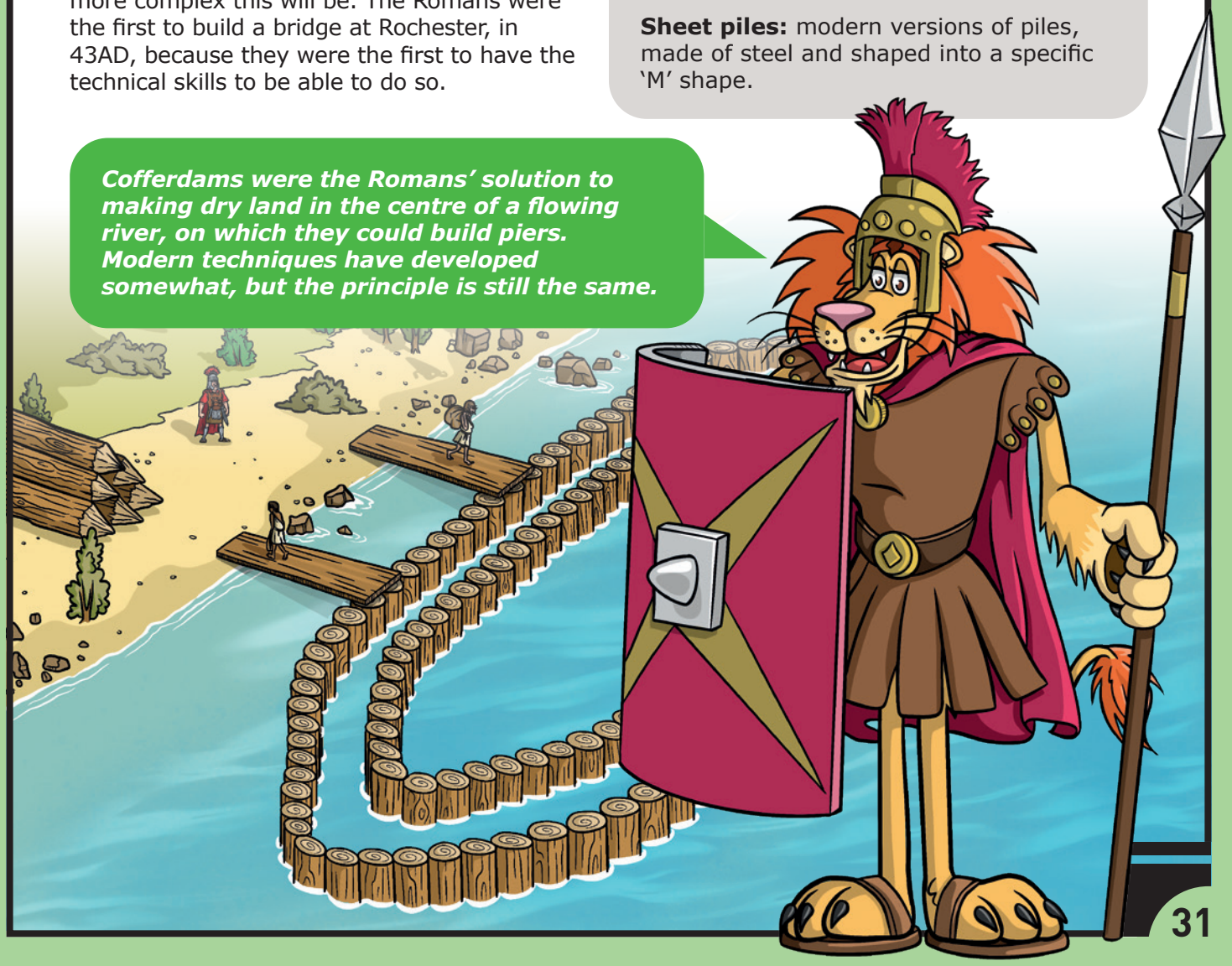
Cofferdam: a temporary box, built in the water, from which the water is removed, leaving a dry space for building.

Piers: the upright columns that support the bridge.

Piles: the large logs with sharpened ends used by Romans to make cofferdams.

Pile-driver: a large weight at the end of a rope, used by Romans to drive the piles into the riverbed. There are modern-day versions of this, which are used to drive in sheet piles.

Sheet piles: modern versions of piles, made of steel and shaped into a specific 'M' shape.



Something to Try:

If we think about how early humans built their bridges, the very first bridges were simply logs across small streams. The spans of these bridges were limited by the length of the logs available.

Then people worked out they could pile rocks and stones in shallow rivers and streams to make piers in the centre to allow their bridges to be longer. But these only worked when the flow of the river was gentle enough not to wash away the rocks. If the water was gentle and shallow, it might just be easier to wade across the river! So early humans usually found an easier place to cross, even if it meant they had to go a long way round. The problem was, people needed to cross rivers, even when the water was rushing past. How could they build a pier in the middle of a river?

You will need...

- Cofferdam Activity, for each group or demonstration:
  - Deep waterproof tray (e.g. Large roasting tin or seed tray without drainage holes)
  - Empty 2 litre plastic bottle
  - Empty 500ml plastic bottle
  - Sand
  - Water
  - Scissors
  - Plastic syringe (for example, the type used for children's medication) or a pipette
  - Bowl or jug
  - Sheet of A4 paper
  - Handout: *Building a model cofferdam*
- Working under water demonstration:
  - Sticky tack/modelling clay/ plasticine/PlayDoh®
  - Plastic milk bottle lid
  - Large bowl/container/bath containing water
  - Wide-necked drinking glass or jar
- Diver Challenge, per group:
  - Approximately 20 Lego®, Duplo® or similar sized building bricks
  - A tray or shallow box
  - Optional: a towel or blanket

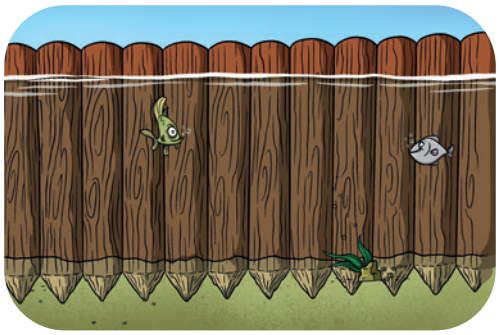
The Romans were not going to be put off by this challenge. They liked to build their roads straight and if there was a rushing river in the way they would just have to find a way to build piers in the water. The solution was a cofferdam.

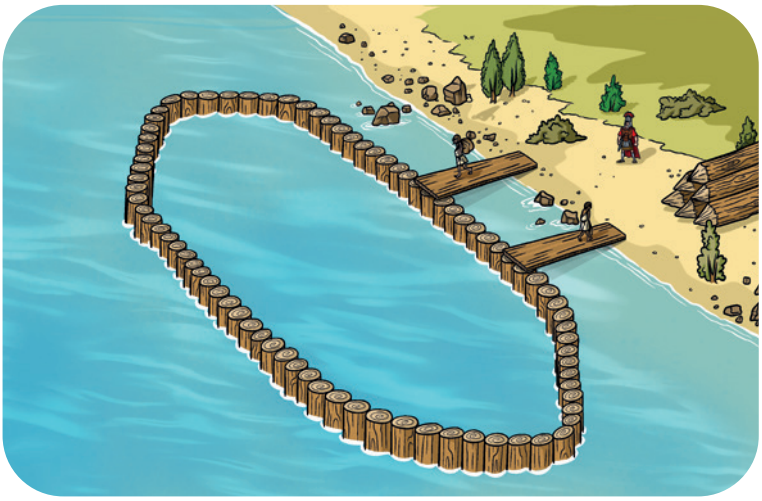
A cofferdam is a temporary box, built in the water, from which the water is removed leaving a dry space for building. In other words, a cofferdam blocks the water on all sides and makes a dry place in the middle of the river where the pier can be built.

First the Romans collected large logs and sharpened the ends. These logs are called piles. Then they pushed the piles into the river bed near where they wanted to build the pier of the bridge.

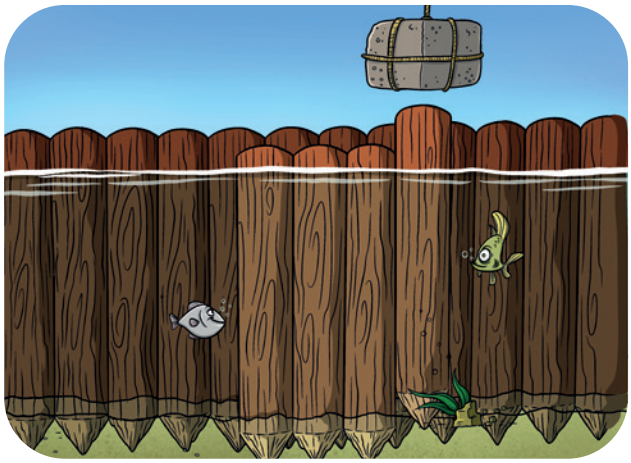
To get the logs into the river bed they invented a machine called a pile-driver. This used a large weight on the end of a rope which hammered the pile into the soft river bed.

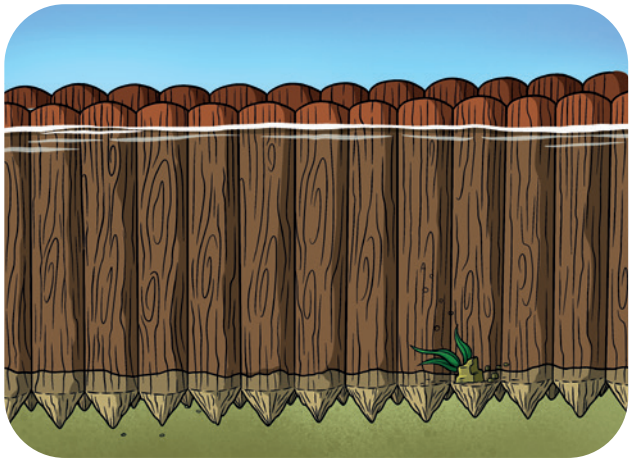
The Romans repeated this until they had made a ring of logs very close together and much bigger than the pier they needed to build.



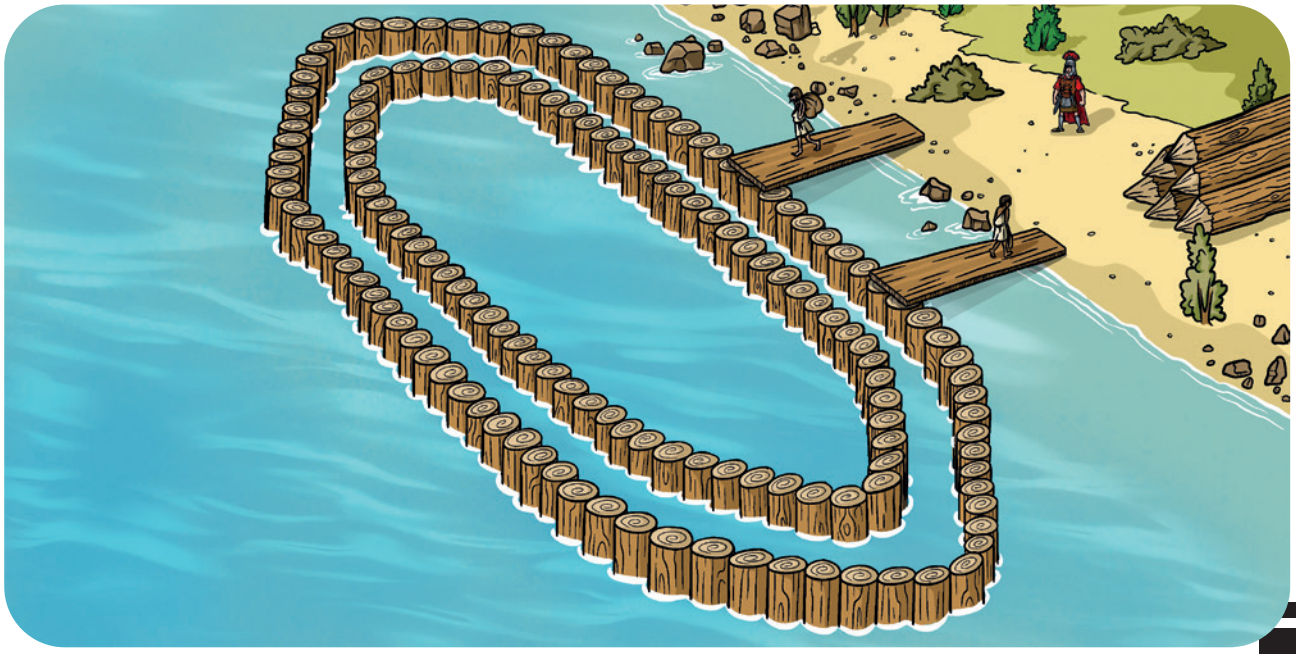


Then they started again and made another ring of logs outside the first one.

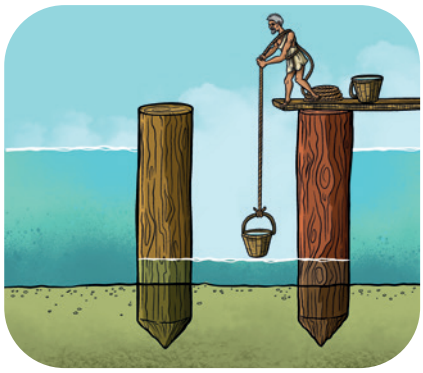


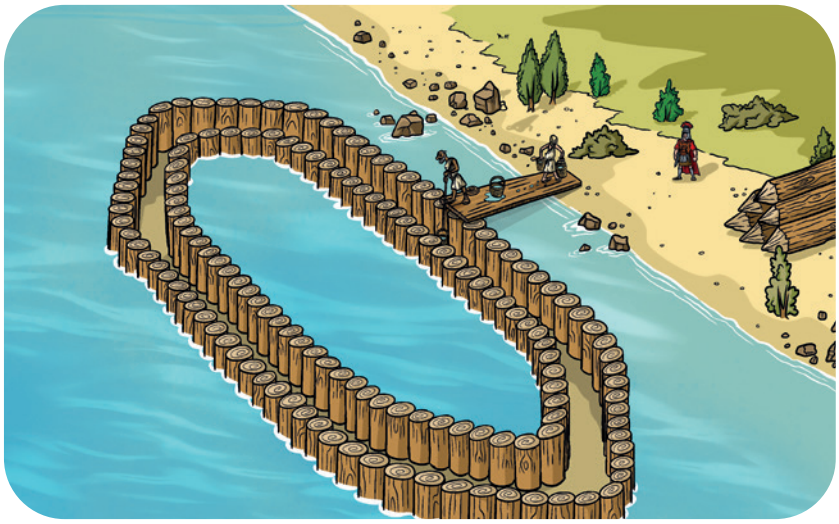


When they were finished, they had made concentric rings of piles.



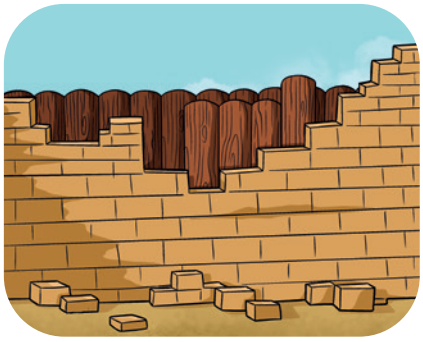
They would then bail out the water between the two rings, likely using a bucket.



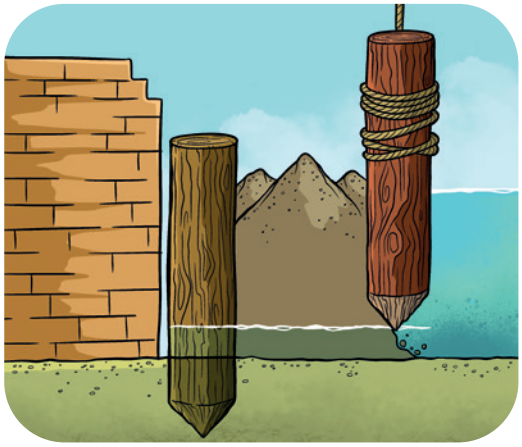


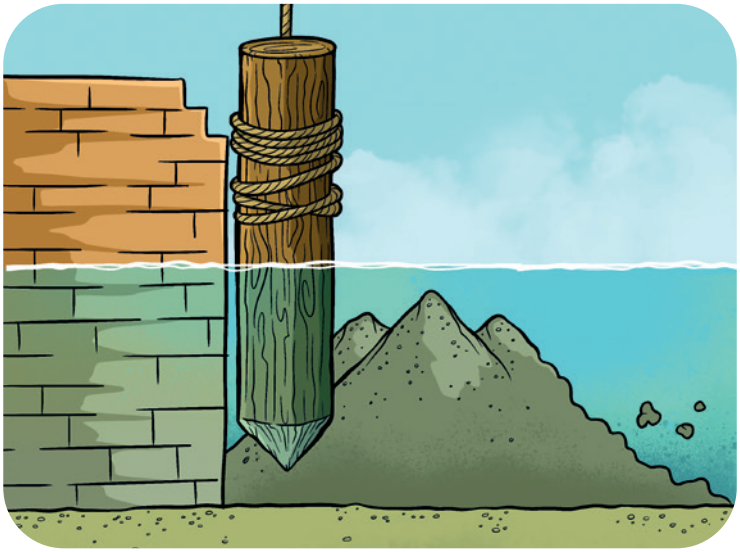
Next they filled the space between the two rings with clay, packing it down as tightly as they could to push all the water out of the gap. They were trying to make the space as waterproof as they could.

When this was done they bailed out the water from inside the middle ring, leaving themselves with a fairly dry space.

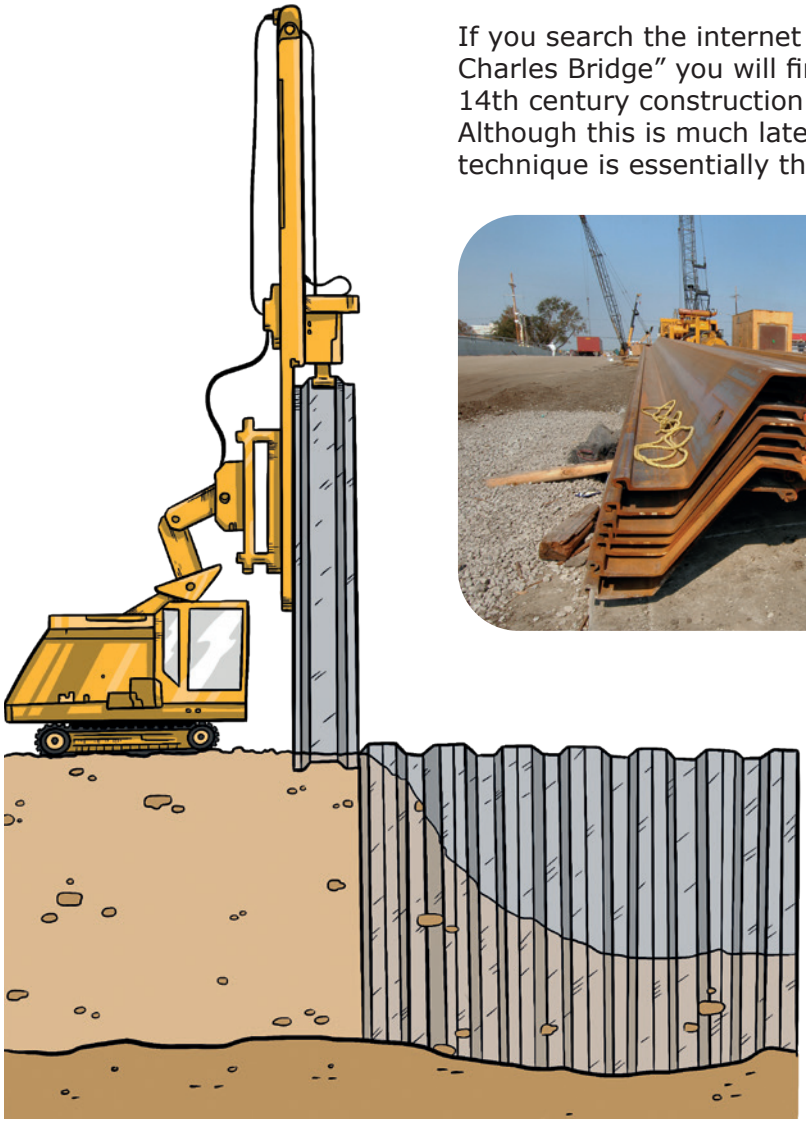


Now the Roman engineers could work in the dry ring and dig out the river bed until they reached the rock underneath. Then they built their bridge piers as high as they needed and added the deck.





Once the bridge was finished they could take away the cofferdam.



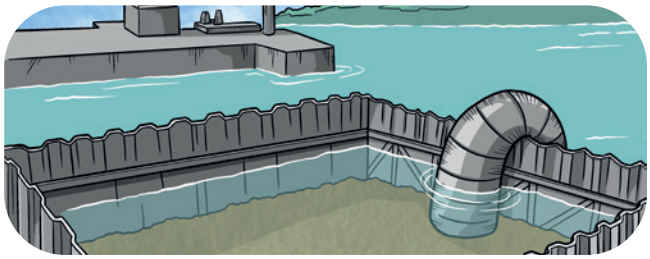
If you search the internet for "Engineering and architecture Charles Bridge" you will find an animation depicting the 14th century construction of the Charles Bridge in Prague. Although this is much later than the Roman period, the technique is essentially the same.

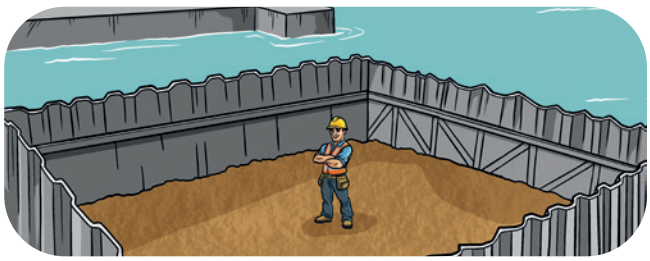
Photo by Alan Dooley of the US Army Corps of Engineers via Wikimedia

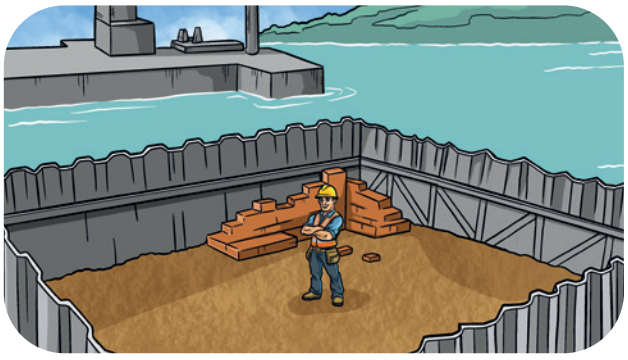
Today civil engineers still use cofferdams and the technique for building them is very similar to the Roman method. Instead of sharpening logs, however, modern engineers tend to use sheet piles. These are made of steel and bent into a special shape.

A modern-day pile-driver is used to push the sheet piles into the ground or the river bed.

Large pumps are used to remove the water from inside the cofferdam.







Once the space is dry, work can begin. Sometimes water needs to be continuously pumped out of the cofferdam, to keep the working area dry and safe for the workers.

BUILD A MODEL COFFERDAM:

Follow the instructions here or use the *Building a model cofferdam* handout.

1

Cut off the top and bottom of the bottles to create two cylinders about 12cm high.

2

Fill the tray with sand up to a depth of about 4cm.

3

Add water until the level is about 3cm above the sand.

4

Insert the larger cylinder in the sand and water until it is flush with the bottom of the tray.

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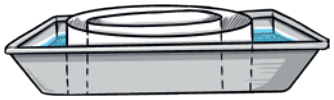
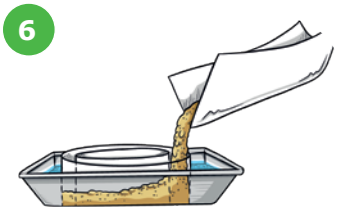


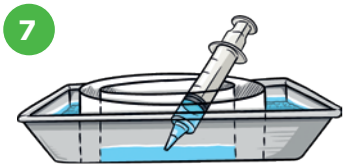
Insert the smaller cylinder into the centre of the first until it is also flush with the bottom of the tray.

6



Fold a piece of paper down the centre and use it as a chute to pour sand into the space between two cylinders.

7



Use the syringe or pipette to remove the water from the centre section into the small bowl until the water level inside the ring is significantly lower than the outside.

Since there will not be a true, water-tight seal around the bottom of the cylinders, it will probably not be possible to remove all of the water from the inner ring. This is not a problem: the Romans were not able to achieve a completely dry cofferdam either and would have had to bail out water throughout their construction process. However, it should be possible to get the water level in the inner ring significantly lower than the rest of the water in the tray.

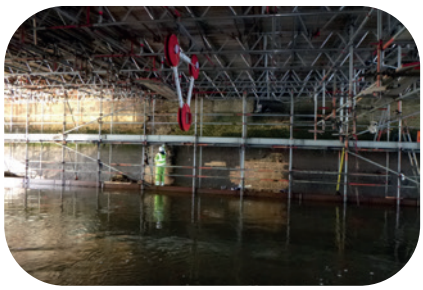
The bottles used in this activity can be replaced by parts of drainpipe, which can be re-used a number of times.

The important thing is to understand how civil engineers use structures like cofferdams to make building bridge piers possible in water.

Vauxhall bridge cofferdam

Challenge Time!

DIVER CHALLENGE: BRICK INSPECTION



Bridges need to be maintained to ensure they stay strong enough to support their loads. The piers underwater need to be inspected to make sure nothing is damaged and needs repairing. To do this, divers enter the water at low tide and inspect the masonry in the piers. The visibility is very poor, so they do this by touch – they have to feel for any bricks that are missing or damaged, or mortar that is missing, to ensure the masonry won't fail. This activity mimics that process.

Use Duplo® or similar toy construction blocks to build a wall with several gaps between the bricks, representing cracks in the structure. Aim for a wall which is 5 rows high and approximately 3-4 long bricks wide. This can be laid on its side in the tray/shallow box.

Keep it hidden from the learners using the towel/ blanket if you have one.

Learners should take on the role of an underwater diver who must gather information on the state of the wall, whilst working in poor light. They should be blindfolded, and have to use only touch, to work out where the gaps are in the wall and report this to a partner, who must make notes of what they say.

The aim is to accurately and systematically record where all the gaps are from touch alone.

The activity can be repeated several times, with the wall being rebuilt many times with the cracks in different positions each time.

HOT TOPICS!

The construction of the Brooklyn Bridge in New York, USA, was riddled with set-backs as a result of accident or illness. One of the issues was something called Caisson's Disease. In fact, the first ever identified cases of Caisson's Disease occurred at the building of the Victorian Rochester Bridge. You could research what is Caisson's Disease and why labourers suffered from this during the construction of the Brooklyn Bridge. You could also explore why Emily Warren Roebling's involvement in this bridge's construction was so remarkable.

Photo by Alexander Rotker on Unsplash

EXPLORING ENGINEERING UNDER WATER:

This demonstration helps to show your learners how engineering work can be carried out under water.

a) Take a piece of sticky tack or PlayDoh® and make a small person.

b) Balance them on the inside of a lid from a plastic milk bottle. This represents your engineer, who is going to be working under water.

c) Float the lid containing your engineer, on the surface of a large bowl or bath of water.

d) Take a glass with a wide opening, such as a pint glass, and carefully place it over the top of the plastic lid/engineer.

e) When you gently push the glass down under the water, what do you notice happens? Keep the glass vertical and with the opening pointing downwards as you move it up and down in the water. Is the engineer wet when they return to the surface?

OUT & ABOUT

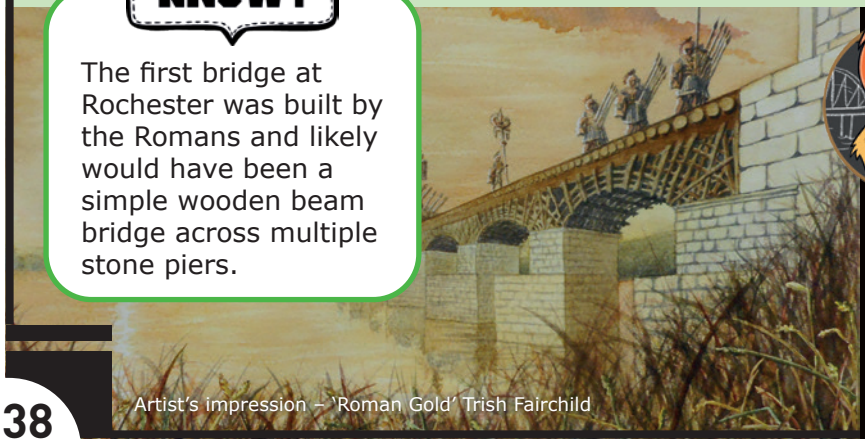
The first Roman bridge over the River Medway was built to allow Roman forces to travel directly to London without deviating to the nearest alternative crossing point. Many towns grew up around fords or bridges and are named after them, Stratford, Bradford, Cambridge and Tonbridge are examples. Some places have a name ending in -brook, -burn, -bourne or -beck. These are all other names for a stream. Can you use a local map and list as many places as possible, named after river crossings?

Also, in some places, people used to have to pay a fee, called a toll, to cross the bridge. Some tollhouses, where the toll collectors lived, still exist. Are there any near where you live?

GEOGRAPHY

DID YOU KNOW?

The first bridge at Rochester was built by the Romans and likely would have been a simple wooden beam bridge across multiple stone piers.



Artist's impression – 'Roman Gold' Trish Fairchild

Langdon presents:

- *Building a model cofferdam* handout

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