Chapter Hi: Enemies of Bridges – The Environment

AIMS & OBJECTIVES

- To know factors that affect a bridge
- To recognise the impact 'thermal expansion' has on a bridge
- To consider the impact rusting has on materials and bridges

CONTEXT

Weather, such as rain, salt water and animals, such as pigeons, all negatively affect the materials from which bridges are made. The result can often be a reduction in strength or function, with time. In this session, we explore the different environmental factors that affect bridges.

LANGUAGE OF BRIDGES:

Chemical weathering: the weathering of materials due to chemicals – including rain water which is slightly acidic due to carbon dioxide from the atmosphere being dissolved in it.

Corrosion: the chemical change in metal due to environmental factors.

Physical weathering: the effect of temperature change on materials, causing them to break apart over time.

Thermal expansion: the change in a material (getting longer, deeper, wider) as a result of heating.

Weathering: the breakdown of materials as a result of the weather, such as rainwater or temperature changes.

You will need...

Demonstrations:

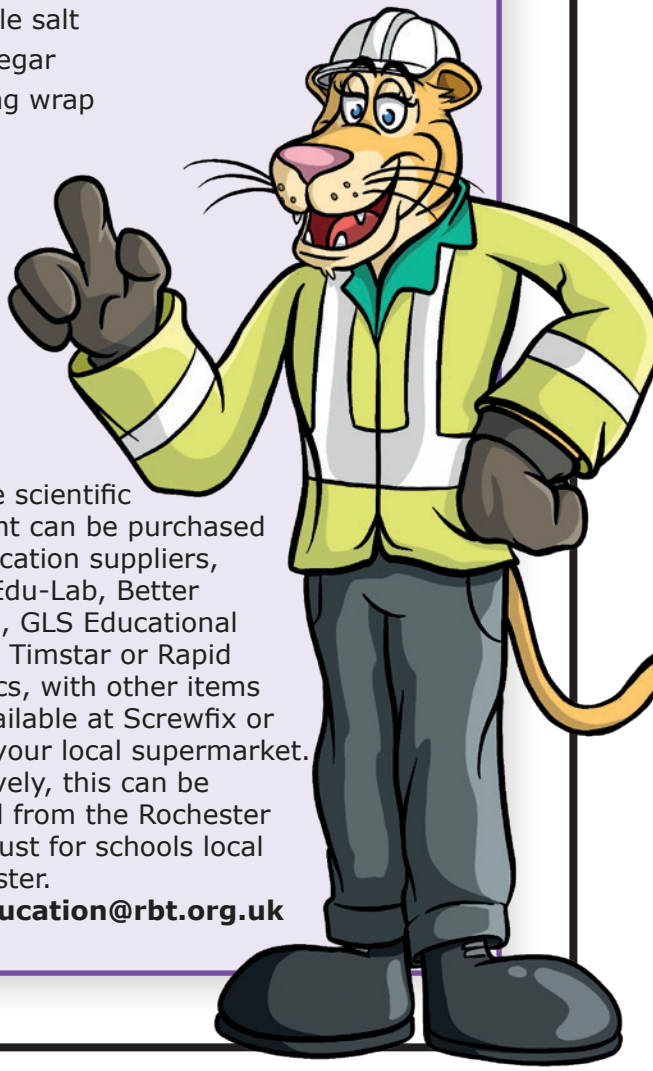
- Expansion of water:
  - Rigid plastic (NOT silicon) ice cube tray (e.g. from Wilkinson's, John Lewis or any other supermarket or similar retailer, eBay or Amazon)

  - Freezer
- Expansion of water causing weathering:
  - Egg
  - Safety pin
  - Bowl
  - Wax (from a candle)
  - Matches/lighter/tealight
  - Egg box/egg sized container
  - Syringe – a single use 10ml plastic one, without needle (available through retailers such as Amazon, eBay, or via TTS group, and other healthcare suppliers)

  - Freezer
- Expansion due to heat:
  - Spirit burner and methylated spirits, or kitchen blow torch
  - Ball and ring demonstration equipment and/or bar and gauge demonstration equipment
  - Heat proof (bench) mat, or similar item, such as a heavy wooden chopping board, to protect the work surface
  - Matches/lighter
  - Safety glasses

Experiments:

- Rusting Iron experiment – per group:
  - Handout: *Exploring rusting*
  - Steel wool (you can use iron nails if you have them instead, but ungalvanized iron nails are difficult to acquire)
  - Gloves – slightly thick ones, such as garden gloves, construction gloves, or heavy duty kitchen gloves, to protect the hands when handling the steel wool
  - Plate/container/paint palette – we used a set of paint pots in a tray from Baker Ross, to keep them all together, but a standard paint palette, or small individual plastic tubs, such as clean yogurt pots, would also be fine
  - Cooking oil
  - Water
  - Table salt
  - Vinegar
  - Cling wrap



The more scientific equipment can be purchased from education suppliers, such as Edu-Lab, Better Equipped, GLS Educational Supplies, Timstar or Rapid Electronics, with other items being available at Screwfix or B&Q, or your local supermarket. Alternatively, this can be borrowed from the Rochester Bridge Trust for schools local to Rochester.
Email **education@rbt.org.uk**

Something to Try:

Ask learners to imagine a bridge, where specifically is not important. Invite them to share ideas about what might happen to that bridge throughout the day, week, month or year. Ask them to imagine what might be different in the summer compared to the winter.

Ask learners to consider the impact of weather on the bridge: the aim is not to get too complicated, but just to start to appreciate that weather will affect materials outside. So rain will get it wet, wind may cause it to move/tip over, sunshine will cause it to heat up.

By Dominicus Johannes Bergsma - Own work, CC BY-SA 4.0

Weather has a chemical or physical effect on materials, including rock, concrete and metal.

Learners may not appreciate that water expands as it freezes. Using an inflexible, hard ice cube tray, you can demonstrate that ice cubes bulge slightly at the top after freezing.

Freeze-Thaw "wedge" weathering – when water gets into cracks and freezes, expanding as it does so.

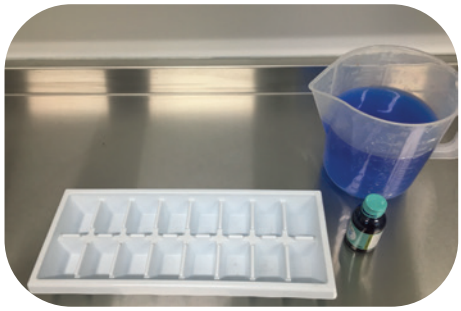
You can also use an egg to demonstrate the destructive power that is generated by the expanding water, and shows how rocks can be weathered by the 'freeze-thaw' process.

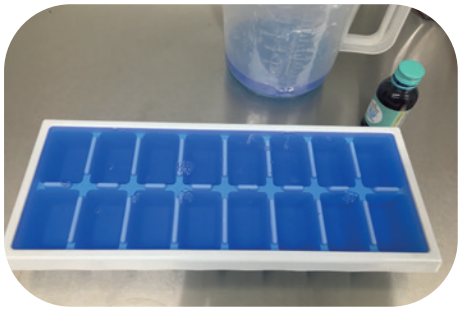
DEMONSTRATION: EXPANSION OF WATER

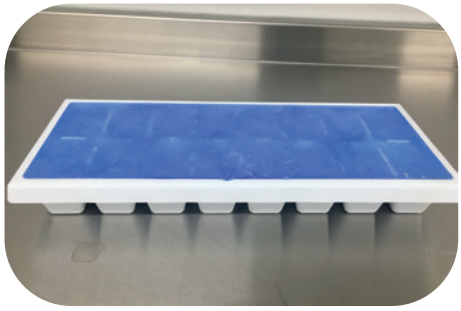
Frozen ice cubes in a rigid ice cube tray: fill the ice cube tray with water right up to the brim.

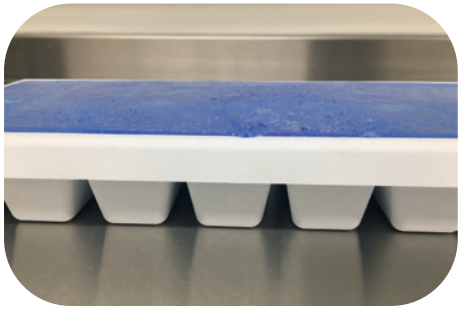
You might like to add food colouring, to colour the water a contrasting shade, to make it stand out in comparison.

Place this in the freezer until fully frozen and then examine what has happened.









HOT TOPICS!

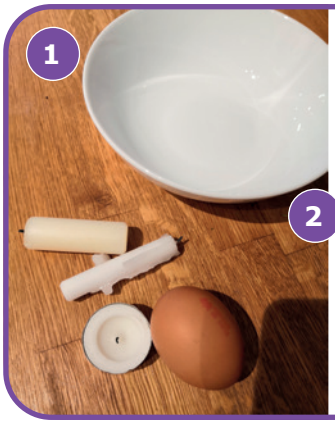
Take inspiration from the artist Andrew Goldsworthy and create some art from natural/outside materials. Take photos over a period of time, and then review how the weather and environment have changed the art work.

Play Jenga. As the pieces are removed from the stack, it weakens the whole pile. This is similar to how the rusting process weakens iron.

Photo by Michał Parzuchowski on Unsplash

DEMONSTRATION: EXPANSION OF WATER CAUSING WEATHERING

This is a bit fiddly, so is probably best shown as a demonstration, but can be carried out by learners too.



1. Using a pin, put a small hole in each end of an egg. These should be big enough to fit the syringe into at a later stage.
2. Blow through one of the holes, until the contents of the egg are removed (collect these in the bowl), taking care not to damage the eggshell as far as possible.

3. Using the candle or wax, seal one of the holes. If you have a tealight, the candle/wax can be melted over the tealight more easily.

4. Using the syringe, refill the egg shell with water.

5. Carefully, seal the second hole using the wax.

7. Place this egg either in a small freezer-safe container, or 'glue' using the candle/wax back into an eggbox section.

8. Place the egg in the container into the freezer for at least four hours (depending on the temperature and efficiency of the freezer).

The freeze-thaw process can also cause deterioration or damage to concrete– when water inside the concrete freezes, it expands and then causes the concrete to 'flake' away.

If you leave the egg to defrost, the water will obviously melt and run away (make sure you leave it somewhere water-proof!), you can more clearly show how rock, stone or concrete can 'flake' away after water has penetrated it. You could invite learners to consider what would happen if water got into the egg again somehow, and froze: this would mimic the repeated exposure of structures to the freeze-thaw process in winter.

DEMONSTRATION: BALL AND RING/BAR AND GAUGE

Although quite straight forward and an effective demonstration, it will require a risk assessment and the purchase of some specific equipment. The technique is simple, but when using any sort of heat source or open flame, care should be taken. Safety glasses are included in the equipment list as a precaution. This demonstration is also available to view as short videos on the Rochester Bridge Trust's education website **www.rochesterbridgetrust.org.uk**

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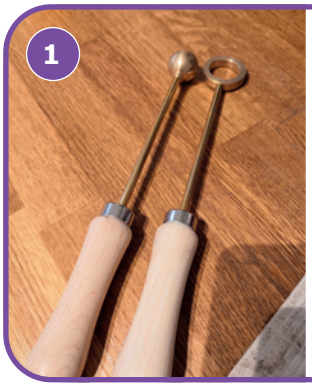

Check the equipment – if the ball fits relatively easily through the ring, the ball needs to be heated for this demonstration (often referred to as Gravesande's ring, or Gravesande's experiment). If the ball is too large to fit through at room temperature, the ring must be heated. Demonstrate this for the learners.

2 Place the spirit burner on the heat proof mat, allowing room to lay the ball and ring equipment with the metal ends on the mat also.

3 Light the burner.

4

Heat the metal ball in the flame for a few minutes, taking care to move it around and warming the surface as evenly as possible.

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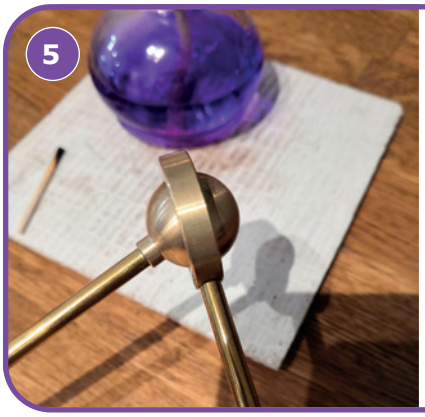


Carefully try to push the ball through the ring – if it is heated sufficiently, it will no longer fit: the metal has expanded with the heat.

Expansion of metal, and other materials, with heat is a problem faced in structures, including bridges. Engineers have had to develop ways of dealing with this.

Links to *Learning About Bridges Vol 2 Chapter Ii: Protecting the Bridge*

Bridges are made from metal: in fact, since the Industrial Revolution, and the possibility of transportation of such useful materials across the country, more bridges were built from iron (cast iron originally) and later steel.

Ask learners how do you think rusting affects metal bridges?

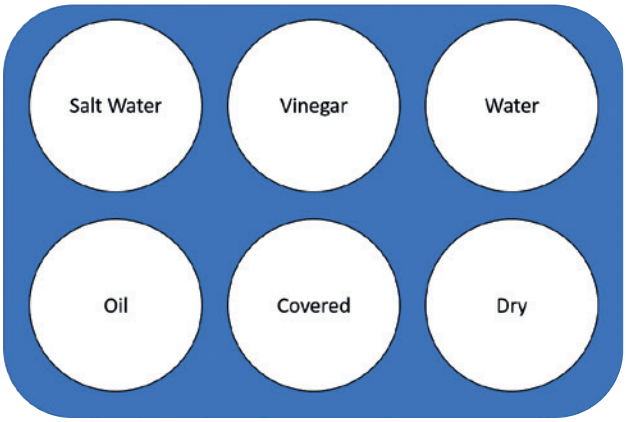
Water encourages metal to rust and, over time, fatigue (or damage) to the metal. Rusting is when the outer layer of the metal reacts with oxygen (oxidises) and turns red. This new material is weaker than the original iron, and more easily flakes away from the metal. This then leaves the iron exposed to more rusting.

Challenge Time!

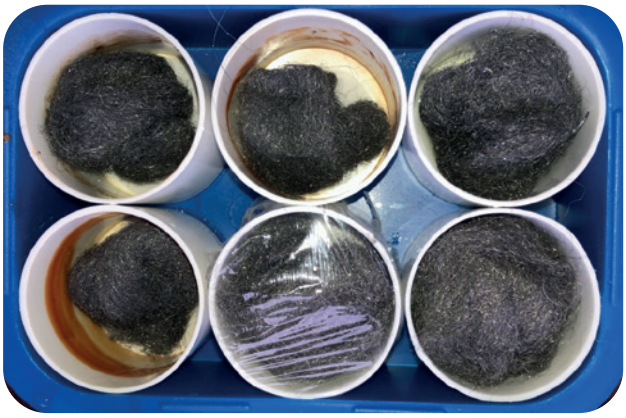
This will need to be set up in advance if you wish to view this within the same session. However, it can be used as an introduction to the 'Bridge Work' chapter too.

Learners will explore how rusting happens, by setting up an experiment with different conditions for the steel wool, to see if the steel rusts. You can use the *Exploring rusting* handout to guide learners through the process.

Label your pots, or draw a diagram to show which pot will contain which substance:



1. Using separate containers for each fluid, put some fresh, clean cold water in one. Approximately 150ml, to ensure that all samples have the same volume.
2. Add about a tablespoon of salt to approximately 150ml of water in a second container, stir.
3. Add the same volume of malt vinegar or distilled vinegar to another container.
4. Pour the same volume of oil to a fourth container.
5. Add a small ball of steel wool, roughly the same size to each other, to each container.
6. Leave them to soak for a few minutes, turning them over in the container, until they are fairly saturated.
7. Add a small ball of steel wool to one of the clean labelled pots, and use the cling wrap to cover the dry steel wool in the container.
8. Place all 6 containers together to one side, where they can be left undisturbed for a few days or so. You may find you need to return to the experiment sooner, depending on the temperature and humidity of the location.
9. Ask learners what they notice has happened to the steel wool.



The BBC Bitesize website offers some Science clips on changing materials, if you search for rust, or what is rust.

You could explore rusting and weathering in your local environment – you could take photos of statues that have been changed over time, or perhaps take pictures of structures that have rusted.

Pot holes in the roads are examples of every-day freeze-thaw weathering in action. When water gets underneath the road surface and freezes, it expands and pushes the road surface up. When the ice melts again, the 'hole' under the road surface makes it weak, so it can get broken by vehicles going over the top. This creates small holes and cracks in the road surface, which allows more water to get in, and in turn, freeze, expand and make even bigger holes!

HOW IS A POTHOLE FORMED?

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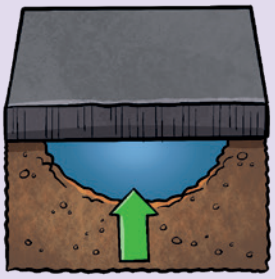
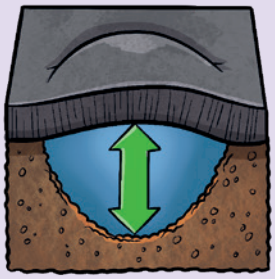


Water accumulates between the asphalt and the subgrade under the road.

2



Cold freezes the water, causing it to expand and form a bump in the road.

3

Above-freezing temperatures thaw the ice, creating a cavity under the road.

4

Weight from passing vehicles causes asphalt to collapse, creating a pothole.

Langdon presents:

- *Exploring rusting* handout

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