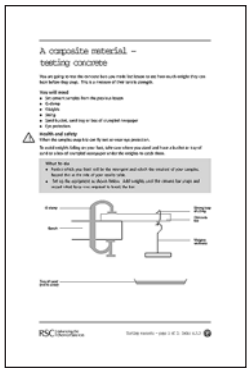
A composite material: concrete


Composite materials


A composite material – making concrete


A composite material – testing concrete

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In this activity students make concrete with various additives then investigate how changing the additives can change the properties of the resulting composite. Concrete is a mix of cement, water, sand and gravel. In the first lesson students prepare samples of concrete and leave them to set. In the second lesson they test their samples for strength.

The written activity **Composite materials** could be used alongside the practical work (**A composite material – making concrete** and **A composite material – testing concrete**).

Equipment required

Quantities will depend on how many samples each group or pair of students is to make.

- Cement (**Corrosive**)
- Sand
- Gravel
- Teaspoons (at least one each for cement, sand and gravel per class)
- Paper clips or wire of similar thickness
- Plaster of Paris (**gets hot when mixed with water**)
- Wooden sticks or splints
- Other possible additives that could be tried include talc, flour, clay
- Plastic cups or yoghurt pots
- Disposable stirrers (lolly sticks or plastic spoons would be suitable)
- Newspaper
- Moulds – see note below
- Large rubbish bag
- Eye protection
- Disposable gloves.

For testing the concrete:

- Set samples from the previous lesson

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- G-clamp
- Weights – the type that fit onto a hook are best
- String – needs to be strong or it will break before the cement samples
- Sand bucket or sand tray
- Eye protection.

Health and safety

Session 1 – making the cement: Cement is corrosive. Avoid raising dust. Wear eye protection. Avoid skin contact. Those with cuts, eczema or sensitive skin should wear gloves. Students should wash their hands at the end of the experiment.

Session 2 – testing the cement: Wear eye protection. Care should be taken that weights do not fall onto students' feet. A tray of sand or a box containing tightly scrunched up newspaper should be placed where the weights will fall.

Note on moulds

There are a number of possibilites for the moulds. Students can make their own from card but this is fiddly and time consuming. Ice cube trays can be used but it is sometimes hard to extract the samples and the resulting cubes of cement are short so they can be difficult to test. The best moulds are the trays that new test-tubes come in, cut up into individual pieces. These can be re-used several times and give a good shape for testing. Similarly, boiling tube trays can be used. However, about twice as much cement is required to fill these and far more force is needed to break the resulting samples.

The instructions on the student sheets are based on the quantities required for a mould made from a test-tube tray.

Avoiding blocked sinks

Ensure that students are aware that none of the materials used or produced in this experiment should be washed down the sink. Any spare cement mix can be tipped onto newspaper on their benches and thrown away. Plastic pots and disposable stirrers do not need washing up and can simply be re-used for each sample required or discarded and a new pot used each time.

To keep students away from sinks, water bottles or beakers of water could be provided for use when making the mixtures.

Possible alternatives

Students could investigate how changing the size of the pieces of gravel or the proportion of it in the mix changes the properties of the resulting concrete.

The compression strength of the samples could be tested instead of, or as well as, their tensile strength. G-clamp a piece of the sample to the table very lightly so it is just held in place. Count how many quarter turns of the clamp it takes until the sample breaks. This test could be carried out on samples that have been tested for tensile strength or on separate samples.

Further information on composites

http://www.science.org.au/nova/059/059key.htm (accessed December 2005) – an excellent Australian site with a good overview of composites; includes links to some interesting activities.

http://www.newscientist.com (accessed December 2005) – a search for 'composite materials' gives several articles, many of which are interesting and relevant. A subscription to the magazine or the site is required to view several, but not all of these.

Answers

Composite materials

1. A composite is a material made by combining two or more other materials. It is possible to tell the component materials apart as they do not dissolve or blend into each other.

2. Collagen alone would not be much use in the skeleton because it is very flexible so it would not provide the support required by the body.

3. Composites are particularly important in nature as structural materials. Trees could not stand up and therefore could not grow so tall without wood. We could not stand up and move about without bone.

4.

a. Mud is the matrix and straw the reinforcement.
b. Cement is the matrix and gravel (and sand) the reinforcement.

5. Answers will vary. Glass and carbon composites can be used in applications ranging from construction to sports equipment. Shiny helium balloons are made from a composite of aluminium foil and polyester sheeting. There are many composites in use today in a wide variety of ways.

6. Composites are important in the A380 because they help to keep it light. This is very important in getting such a big plane off the ground.

7. Using composites will mean that cars and aircraft can be made lighter. If vehicles are lighter they require less fuel to move them from place to place. Less fuel means lower emissions.

Testing concrete

1. Answers will vary. Mark by impression.

2. The answer to this should be no. Just one sample was used for each test. The amount of water used to make the various samples may have varied and this could affect the strength. There may have been a crack in the sample already. Various other things could prevent one particular sample from being representative of all samples made to a set of specifications.

3. In many ways it is not. The exact position of the G-clamp on the sample and where the weights hang will affect exactly what force is exerted. The weight of the samples varies.

4. Answers will depend on students' results. Gravel of the right size will increase the strength but if the pieces are too big the strength may be reduced. Paper clips will almost certainly make the concrete stronger. Adding steel makes steel-reinforced concrete, which is widely used as a building material.

Composite materials

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart as they do not dissolve or blend into each other.

Natural composites

Natural composites exist in both animals and plants. Wood is a composite – it is made from long cellulose fibres (a polymer) held together by a much weaker substance called lignin. Cellulose is also found in cotton, but without the lignin to bind it together it is much weaker. The two weak substances – lignin and cellulose – together form a much stronger one.

The bone in your body is also a composite. It is made from a hard but brittle material called hydroxyapatite (which is mainly calcium phosphate) and a soft and flexible material called collagen (which is a protein). Collagen is also found in hair and finger nails. On its own it would not be much use in the skeleton but it can combine with hydroxyapatite to give bone the properties that are needed to support the body.

Early composites

People have been making composites for many thousands of years. One early example is mud bricks. Mud can be dried out into a brick shape to give a building material. It is strong if you try to squash it (it has good compressive strength) but it breaks quite easily if you try to bend it (it has poor tensile strength). Straw seems very strong if you try to stretch it, but you can crumple it up easily. By mixing mud and straw together it is possible to make bricks that are resistant to both squeezing and tearing and make excellent building blocks.

Another ancient composite is concrete. Concrete is a mix of aggregate (small stones or gravel), cement and sand. It has good compressive strength (it resists squashing). In more recent times it has been found that adding metal rods or wires to the concrete can increase its tensile (bending) strength. Concrete containing such rods or wires is called reinforced concrete.

Making composites

Most composites are made of just two materials. One is the matrix or binder. It surrounds and binds together fibres or fragments of the other material, which is called the reinforcement.

Modern examples

The first modern composite material was fibreglass. It is still widely used today for boat hulls, sports equipment, building panels and many car bodies. The matrix is a plastic and the reinforcement is glass that has been made into fine threads and often woven into a sort of cloth. On its own the glass is very strong but brittle and it will break if bent sharply. The plastic matrix holds the glass fibres together and also protects them from damage by sharing out the forces acting on them.

Some advanced composites are now made using carbon fibres instead of glass. These materials are lighter and stronger than fibreglass but more expensive to produce. They are used in aircraft structures and expensive sports equipment such as golf clubs.

Carbon nanotubes have also been used successfully to make new composites. These are even lighter and stronger than composites made with ordinary carbon fibres but they are still extremely

expensive. They do, however, offer possibilities for making lighter cars and aircraft (which will use less fuel than the heavier vehicles we have now).

The new Airbus A380, the world's largest passenger airliner, makes use of modern composites in its design. More than 20 % of the A380 is made of composite materials, mainly plastic reinforced with carbon fibres. The design is the first large-scale use of glass-fibre-reinforced aluminium, a new composite that is 25 % stronger than conventional airframe aluminium but 20 % lighter.

Why use composites?

The biggest advantage of modern composite materials is that they are light as well as strong. By choosing an appropriate combination of matrix and reinforcement material, a new material can be made that exactly meets the requirements of a particular application. Composites also provide design flexibility because many of them can be moulded into complex shapes. The downside is often the cost. Although the resulting product is more efficient, the raw materials are often expensive.

Questions

1. What is a composite?

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2. On its own, collagen would not be much use in the skeleton. Explain why not.

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3. Why are composites important in nature?

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4. What is the matrix and what is the reinforcement in:

a. mud bricks?

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b. concrete?

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5. List four modern composites and give a use for each. Try to include some which are not mentioned in the information above.

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6. Why are composites so important in the design of the Airbus A380?

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7. How can composite materials help to protect the environment and reduce carbon dioxide emissions in the future?

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A composite material – making concrete

A composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties. However, within the composite you can easily tell the different materials apart because they do not dissolve or blend into each other.

You are going to make some concrete and include various additives in the mix. You will then investigate how changing the additives can change the properties of the resulting composite.

You will need two lessons to complete the investigation. In the first lesson, you will prepare the samples and leave them to set. In the second lesson, you will test your samples for strength.

Concrete is a mix of cement, sand, gravel and water.

You will need

- Cement
- Sand
- Gravel
- Paper clips or wire of similar thickness
- Plaster of Paris
- Wooden sticks or splints
- Plastic cups or yoghurt pots
- Disposable stirrers (lolly sticks or plastic spoons would be suitable)
- Newspaper
- Moulds
- Eye protection.

Health and safety

Cement is corrosive. Wear eye protection and try to avoid raising cement dust. Avoid skin contact with the cement. If you have ezcema, cuts or sensitive skin wear disposable gloves.

What to do

- Cover your bench in newspaper. Collect a plastic cup or yoghurt pot. Put 2 teaspoons of cement powder, 4 teaspoons of sand and 6 teaspoons of gravel in the cup or pot and mix them together thoroughly.
- Add water a drop or two at a time. It is easier to add water than to remove it from the mixture and not much is required so add it carefully. Keep mixing until a hole made in the mixture will remain but it can also be poured.
- Pour the mixture into a mould. Label the mould with your name and 'sample 1' then leave the mixture to set.
- Make other samples and include different additives or vary the mixture in other ways. Include some or all of the following: no gravel; wooden splints placed in the mould and the cement mixture added to it; opened paper clips or wire in the mould and the cement added to it; Plaster of Paris powder added to the mix. You could also change the size of the gravel pieces or the ratio of cement, sand and gravel in the mixture.
- For each sample you make, record what it contains in a table like the one below.

Sample number	What it contains	Mass required to break it
1	2 teaspoons cement, 4 teaspoons sand, 6 teaspoons water	
2		
3		

- When you have finished making samples, place them all in a safe place to set. Wrap up the newspaper on your desk, making sure you collect all the dust and bits. Put this into the rubbish bin, along with your plastic mixing pot, stirrer and gloves if you wore them.
- Do not wash up anything that has had cement powder on it.
- Wash your hands.

A composite material – testing concrete

You are going to test the concrete bars you made last lesson to see how much weight they can bear before they snap. This is a measure of their tensile strength.

You will need

- Set cement samples from the previous lesson
- G-clamp
- Weights
- String
- Sand bucket, sand tray or box of crumpled newpaper
- Eye protection.

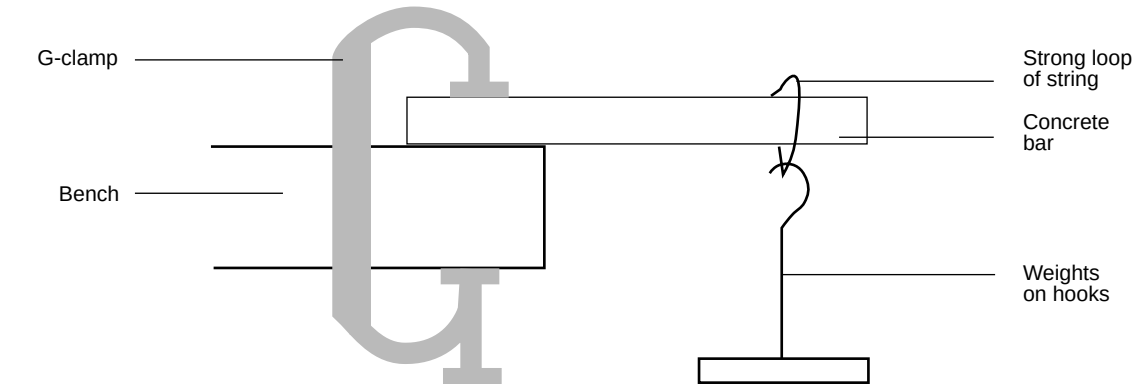
Health and safety

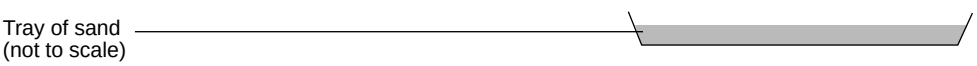
When the samples snap bits can fly out so wear eye protection.

To avoid weights falling on your feet, take care where you stand and have a bucket or tray of sand or a box of crumpled newspaper under the weights to catch them.

What to do

- Predict which you think will be the strongest and which the weakest of your samples. Record this at the side of your results table.
- Set up the equipment as shown below. Add weights until the cement bar snaps and record what force was required to break the bar.





Questions

1. Did your results match your predictions? Were any of your results surprising? Comment on what you have found out.

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2. Would you be able to rely on these results to make definite conclusions about what makes the strongest concrete? Explain your answer.

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3. Is this a fair test? If not, what could you do to improve it?

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4. What do your results suggest should be added to concrete to make it stronger? Try to explain why this works.

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