Other physical properties

Trials of strength

Strength is a very important property to consider when choosing the right material for almost any job. In many cases, it doesn't matter whether the material conducts electricity or heat, nor whether its density is high or low. However, if an object isn't strong enough to do the job, then it's no use. This is obvious for large objects, such as bridges and buildings, but it's equally true for small items: shopping bags, CD cases, keyboards, mugs, screwdrivers. In fact - almost everything!

But what do we mean by 'strong enough'? Compare strips of wood (such as a ruler) and elastic. Wood can support a load, but breaks if bent too far. Even a small load distorts elastic, but it bends without breaking. So which is stronger?

Strength is a complicated concept. The National Physical Laboratory (NPL) describes a material's strength as its ability to withstand large stresses before either breaking or deforming such that the strain is no longer proportional to stress. That probably doesn't help you much. What are stress and strain?

Stress is the force applied per unit of cross-sectional area. Like pressure, stress is measured in N m-2 (also called pascal Pa) but, unlike pressure, stress forces can be applied in different ways. For example, you can apply a **tensile** force (to stretch the material) or a **compressive** force (to squeeze the material). Some materials have good compressive strength, but poor tensile strength, or vice versa.

Strain is defined as a fractional change in length when something is under stress. In other words, when you stretch or squash a material, the strain is the change in length compared with the original length. Because it's a ratio, strain has no unit.

When put under stress, a material will **deform** (change shape). The higher the stress, the more strain it causes. At first the strain is proportional to stress – doubling the stress causes double the strain. The deformation is **temporary** – that is, when the force is removed, the material returns to its original shape.

With most materials, but not all, large stresses produce much larger deformations. This is what the NPL means by "the strain is no longer proportional to stress ". The deformation becomes **permanent** – that is, when the force is removed, the material stays deformed. This is called yielding. If the stress is higher still, the material will eventually break.

Strength is a measure of how much stress a material can withstand before either the strain begins to increase rapidly and the material yields (deforms permanently), or it breaks.

There are different types of force, which may affect materials differently. For example, a sudden **impact** force, a steady **static** force, or a gradually increasing force.
The following example helps to illustrate these terms.

A heavy load stands on the ground near a crane.

The weight of the load is a **static compressive** force, pressing on the soil beneath. The force squashes the soil and **deforms it**.

The crane now lifts the load, by gradually increasing the lifting force.

Once it's off the ground, the hanging load produces a **static tensile** force on the cable. The resulting **stress** in the cable causes a **strain** – that is, the cable stretches slightly. This deformation is only **temporary**. When the load is put down, the cable returns to its original length.

A 'footprint' of the load is left in the ground, because the soil has been **permanently** deformed.

If the crane driver drops the load, the **impact** force will make a dent in the soil larger than the original 'footprint'. It will also **break** anything brittle that it falls on.

These two standard procedures contain tests for you to compare the tensile strength and impact resistance of different materials. You should also investigate how strength is affected by varying the size and shape of a particular material.

Note: The tests are only comparative; they don’t give absolute values. British Standards enable absolute values of different types of strength to be determined. They’re usually specific to a particular type of material such as plastics, paper, ceramics, metal, wood, composites. However, they are difficult to set up in a school laboratory (for example, for tensile strength testing, the load must be applied and increased smoothly).

SP 0012:2005 ***Methods of testing strengths of materials***

Part 1: Comparing the tensile strength of plastics, paper and board

Part 2: Comparing the impact resistance of materials