Choosing Materials in Structural Engineering

Properties of materials

In structural design, important material properties include:

- *Density* - mass/unit volume. Heavy materials add more load to the structure. In aircraft design, for example, keeping the weight down is a very important issue.
- *Strength* **-** stress at failure. Obviously the higher the better.
- *Stiffness* - the ratio of stress to strain, i.e. the E-value. High E-value implies high stiffness
- *Ductility* - the ratio of the strain at failure to the strain at first yield. This is a feature of plastic behaviour.
- *Durability* - the potential for the material to retain its original condition i.e. not to degrade with time or use.
- *Cost*

Indicative values of properties of the main materials used in structural engineering are given in Table 1.

Table 1: Indicative values for properties of main structural materials

Property		**Steel**	**Concrete**	**Timber**	**Masonry**
Density kg/m^3		78	20	8	15
Strength N/mm^2	Tension	220	2	15	low
	Compression	150	60	10	3 to 100
Stiffness E kN/mm^2		196	28	10	6
Ductility in tension		High	Brittle	Brittle	Brittle

Working with the properties

Designers prefer to use materials with low density because that keeps down the load on the structure. Steel therefore scores badly in this respect. On the other hand, it scores very well on the other three properties in the table where high values are desirable.

Before about 1850, the dominant structural materials were masonry and timber. A main structural action is to span, e.g. a bridge spans a river, a roof in building spans between columns. In the past, longer spans tended to be in the form of masonry arches because an arch is in compression and there were no materials that had high enough strength in tension to allow tension to used be for longer spans.

The use of steel

Around 1850 two important events occurred. First, methods for forging steel were introduced to make it available in large quantities. Second, the use of structural mechanics transformed the confidence that structural engineers could have in their designs for spanning. In particular the theory of bending, first published by Navier in 1826, allowed beams to be designed on a scientific basis, more.

Apart from the use of steel beams and columns, the reinforced concrete started to be used around the 1850s.

Ductility

The benefits of high strength and high stiffness are obvious. What about ductility.

Look at these two videos of tests to failure of steel reinforcing bars - [mild steel](), [HT steel]()

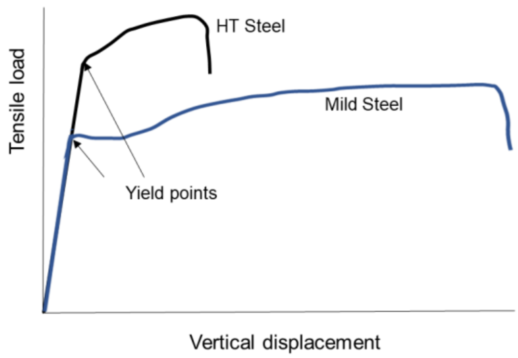

Figure1 Tensile failure in steel

The diagram (left) shows the graphs from these tests. The load/displacement curves are straight (i.e. linear elastic) up to a 'yield point'. Beyond that, the specimens continue to support load but with high displacements. Eventually they break. The change in length of the specimen after yield is called *plastic deformation* that provides ductility

A brittle material has no plastic deformation. At some point it snaps without warning. For example, chalk, as used with a blackboard, is a brittle material.

The advantage of the plastic/ductile behaviour is that there is warning of failure. Large deflections may develop before final collapse showing that failure is approaching.

Note (Table 1) that concrete, timber and masonry are all brittle in tension. They show some plasticity in compression. Timber is used in tension but otherwise metals - steel and sometimes aluminium - take tensile forces. In reinforced concrete, steel takes the tension and concrete takes the compression.

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