1.3 Mechanical properties of steel

1.3.1 Stress – strain behaviour: tensile test

The stress-strain curve for steel is generally obtained from tensile test on standard specimens as shown in Fig.1.4. The details of the specimen and the method of testing is elaborated in IS: 1608 (1995). The important parameters are the gauge length 'L_c' and the initial cross section area S_o. The loads are applied through the threaded or shouldered ends. The initial gauge length is taken as 5.65 $(S_o)^{1/2}$ in the case of rectangular specimen and it is five times the diameter in the case of circular specimen. A typical stress-strain curve of the tensile test coupon is shown in Fig.1.5 in which a sharp change in yield point followed by plastic strain is observed. After a certain amount of the plastic deformation of the material, due to reorientation of the crystal structure an increase in load is observed with increase in strain. This range is called the strain hardening range. After a little increase in load, the specimen eventually fractures. After the failure it is seen that the fractured surface of the two pieces form a cup and cone arrangement. This cup and cone fracture is considered to be an indication of ductile fracture. It is seen from Fig.1.5 that the elastic strain is up to ey followed by a yield plateau between strains ey and esh and a strain hardening range start at esh and the specimen fail at eult where ey, esh and eult are the strains at onset of yielding, strain hardening and failure respectively.

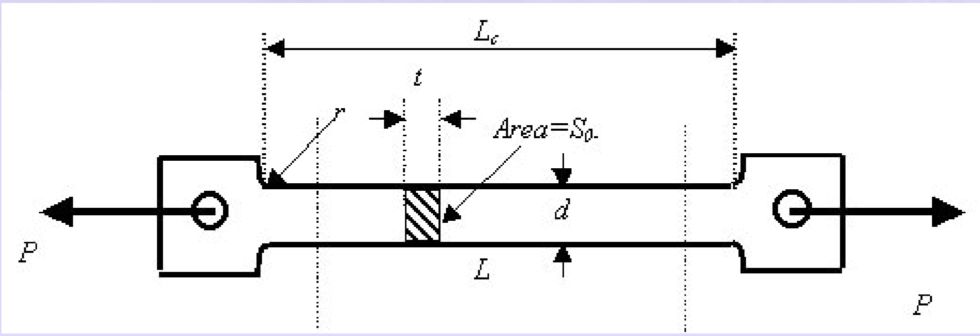

Fig 1.4. Standard tensile test specimen

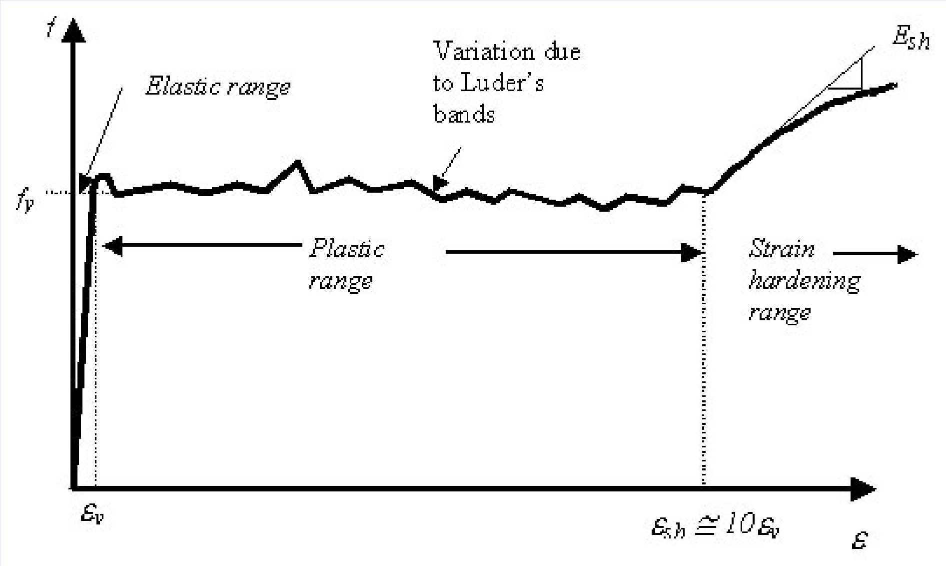

Fig 1.5. Stress strain curve for mild steel

Depending on the steel used, ε_{sh} generally varies between 5 and 15 ε_y, with an average value of 10 ε_y typically used in many applications. For all structural steels, the modulus of elasticity can be taken as 205,000 MPa and the tangent modus at the onset of strain hardening is roughly 1/30th of that value or approximately 6700 MPa.

High strength steels, due to their specific microstructure, do not show a sharp yield point but rather they yield continuously as shown in Fig. 1.6. For such steels the yield stress is always taken as the stress at which a line at 0.2% strain, parallel to the elastic portion, intercepts the stress strain curve. This is shown in Fig. 1.6.

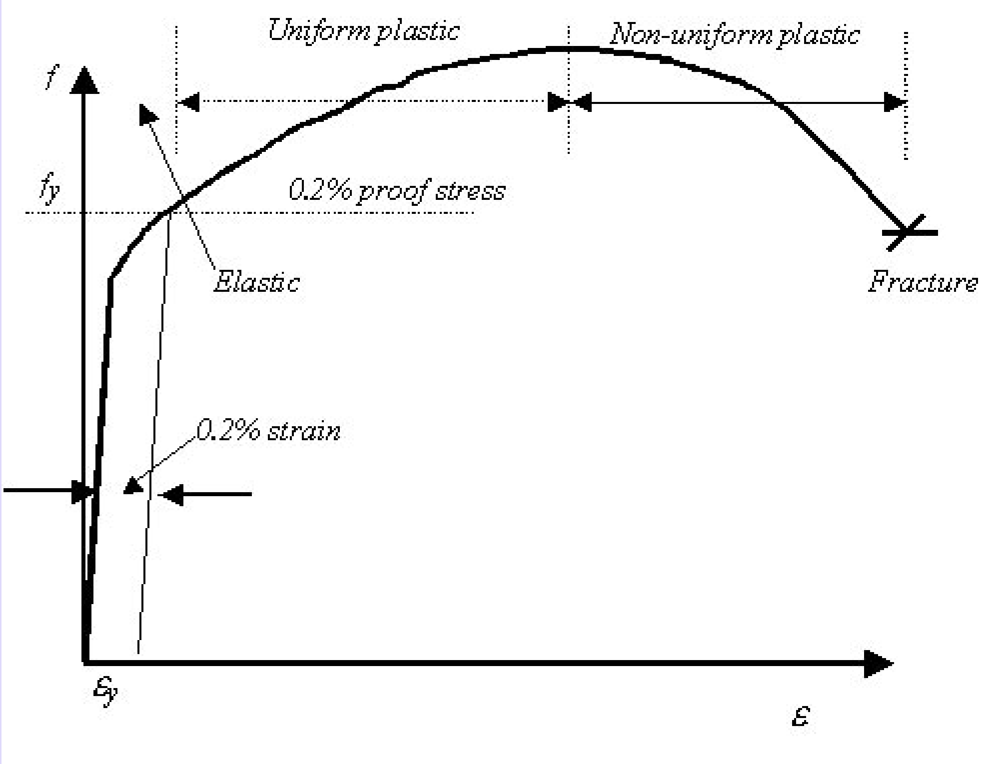

Fig 1.6. Stress strain curve for high strength steel

The nominal stress or the engineering stress is given by the load divided by the original area. Similarly, the engineering strain is taken as the ratio of the change in length to original length.

1.3.2 Hardness

Hardness is regarded as the resistance of a material to indentations and scratching. This is generally determined by forcing an indentor on to the surface. The resultant deformation in steel is both elastic and plastic. There are several methods using which the hardness of a metal could be found out. They basically differ in the form of the indentor, which is used on to the surface. They are presented in Table 1.2.

In all the above cases, hardness number is related to the ratio of the applied load to the surface area of the indentation formed. The testing procedure involves forcing the indentor on to the surface at a particular road. On removal, the size of indentation is measured using a microscope. Based on the size of the indentation, hardness is worked out. For example, Brinell hardness (BHN) is given by the ratio of the applied load and spherical area of the indentation i.e.

Table 1.2 Hardness testing methods and their indentors

Hardness Testing Method		Indentor
(a)	Brinell hardness	Steel ball
(b)	Vickers hardness	Square based diamond pyramids of 135^{o} included angle
(c)	Rockwell hardness	Diamond core with 120^{o} included angle
Note: Rockwell hardness testing is not normally used for structural steels.		

$$BHN = \frac{P}{\pi(d/2)\left[D - \sqrt{D^2 - d^2}\right]} \qquad \textbf{(1.2)}$$

Where P is the load, D is the ball diameter, d is the indent diameter. The Vickers test gives a similar hardness value (VHN) as given by

$$VHN = \frac{1.854P}{L^2} \qquad \textbf{(1.3)}$$

Where L is the diagonal length of the indent.

Both the BHN and VHN for steel range from 150 to 190.

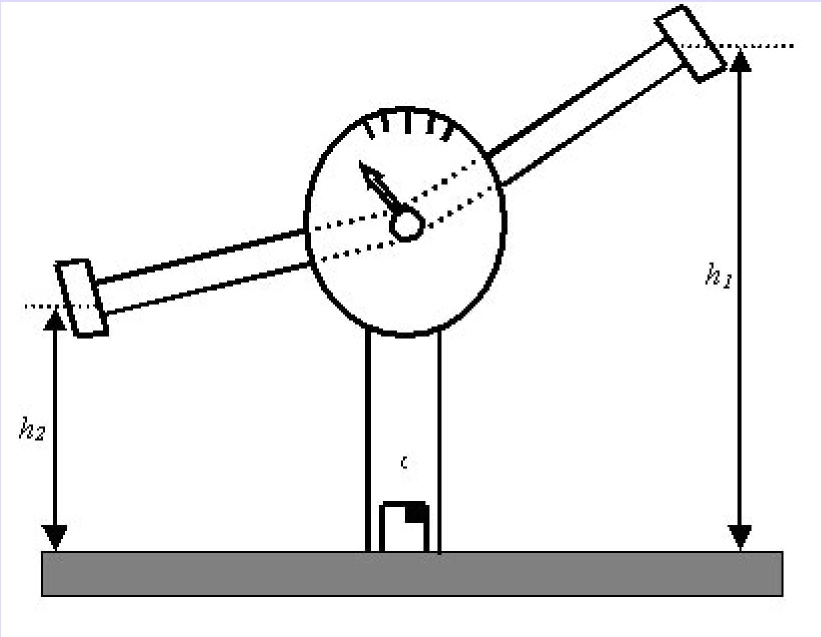

Fig 1.7. Experimental set up for notch toughness test

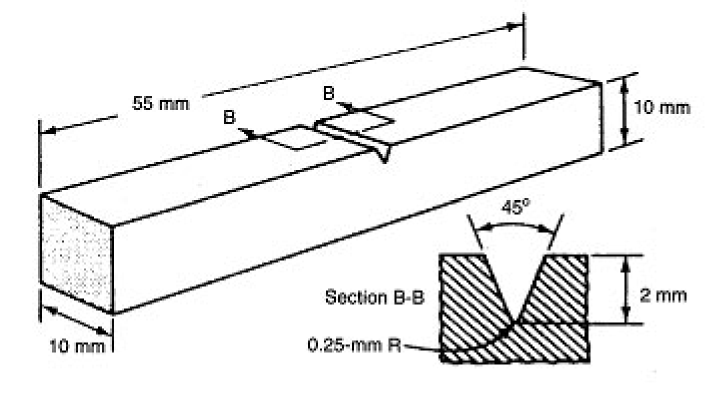

Fig 1.8.Test specimen for notch toughness test

1.3.3 Notch-toughness

There is always a possibility of microscopic cracks in a material or the material may develop such cracks as a result of several cycles of loading. Such cracks may grow rapidly without detection and lead to sudden collapse of the structure. To ensure that this does not happen, materials in which the cracks grow slowly are preferred. Such steels are known as notch-tough steels and the amount of energy they absorb is measured by impacting a notched specimen with a heavy pendulum as in Izod or

Charpy tests. A typical test set up for this is shown in Fig. 1.7 and the specimen used is shown in Fig. 1.8.

The important mechanical properties of steel produced in India are summarized in Table 1.3. In Table 1.3, the UTS represent the minimum guaranteed Ultimate Tensile Strength at which the corresponding steel would fail.

Table 1.3 Mechanical properties of some typical structural steels

Type of steel	Designation	UTS (MPa)	Yield strength(MPa) Thickness (mm)			Elongation Gauge $5.65\sqrt{S_0}$	Charpy V - notch values Joules (min)
			<20	20-40	>40		
Standard structural steel	Fe410A	410	250	240	230	23	27
	Fe410B	410	250	240	230	23	27
	Fe410C	410	250	240	230	23	27
<16 16-40 41-63							
Micro alloyed high strength steel	Fe440	440	300	290	280	22	-
	Fe540	540	410	390	380	20	-
	Fe590	590	450	430	420	20	-