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A Handbook on Civil Engineering

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Editors

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Box No. 4766, 616 Corporate Way,
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Notice

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Preface

Civil engineering is arguably the oldest engineering discipline. It compacts with the built environment and can be dated to the first time someone placed a roof over his or her head or laid a tree trunk across a river to make it easier to get across. The built environment encompasses much of what defines modern civilization. Buildings and bridges are often the first constructions that come to mind, as they are the most conspicuous creations of structural engineering, one of civil engineering's major sub-disciplines. Roads, railroads, subway systems, and airports are designed by transportation engineers, another category of civil engineering. These few examples illustrate that civil engineers do a lot more than design buildings and bridges.

The Handbook covers systems design, community and regional planning, the latest design methods for buildings, airports, highways, tunnels and bridges. It includes sections on construction equipment, construction management, materials, specifications, structural theory, geotechnical engineering, wood, concrete, steel design and construction.

The handbook encompasses all the formulae and important theoretical aspects of Civil Engineering, with appropriate diagrams, whenever it is appropriate. An extensive coverage of key points for additional information is also given.

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Strength of Materials

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1 Properties of Metals Stress and Strain

Often materials are subject to forces (loads) when they are used. Mechanical engineers calculate those forces and material scientists how materials deform (elongate, compress, and twist) or break as a function of applied load, time, temperature, and other conditions.

IMPORTANT MECHANICAL PROPERTIES

The importance of mechanical properties is as:

Elasticity

The elastic limit is the highest stress at which all deformation strains are fully recoverable. For most materials and applications this can be considered the practical limit to the maximum stress a component can withstand and still function as designed. Beyond the elastic limit permanent strains are likely to deform the material to the point where its function is impaired.

Plasticity

It is the ability of the material to deform plastically at elevated temperature under constant load. It occurs even though the applied stress is less than the yield stress at that temperature. Creep characteristics are determined by subjecting the specimen to different constant stresses at elevated temperatures and observing the corresponding strain.

Ductility

Ductility is a measure of how much deformation or strain a material can withstand before breaking. The most common measure of ductility is the percentage of change in length of a tensile sample after breaking. This is generally reported as % El or percent elongation. The R.A. or reduction of area of the sample also gives some indication of ductility.

Brittleness

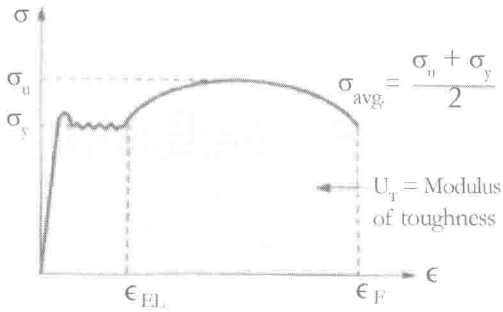
It is the ability of the material to shatter or break before deformation (e.g. iron, glass). This property is actually the opposite of plasticity.

Toughness

It is the ability of a material to withstand sudden loading or to absorb energy until it breaks and it is measured in terms of modulus of toughness. Machine components that are subjected to sudden loading must be made from materials that possess high toughness.

The toughness of a material can be related to the total area under its stress-strain curve. A comparison of the relative magnitudes of the yield strength, ultimate tensile strength and percent elongation of different material will give a good indication of their relative toughness. Materials with high yield strength and high ductility have high toughness. Integrated stress-strain data is not readily available for most materials so other test methods have been devised to help quantify toughness.

$$\text{Modulus of toughness } U_T = \text{shaded area} = \left(\frac{\sigma_u + \sigma_u}{2}\right)\epsilon_f$$



Hardness

It is the ability of a material to resist scratching, abrasion or indentation. It is one of the easiest criterion or measurement in acceptance tests, and quality control of raw stock as manufactured products. Common hardness testing methods are Brunel and Rockwell hardness tests.

Strenght

Strength has several definitions depending on the material type and application. Before choosing a material based on its published or measured strength it is important to understand the manner in which strength is defined and how it is measured. When designing for strength, material class and mode of loading are important considerations.

Creep

The plastic deformation of a material which occurs as a function of time when the material is subjected to constant stress below its yield strength. For metals this is associated with high temperature applications but polymers may exhibit creep at low temperatures.

Fatigue

The number of cycles for which a component or a specimen can endure an alternating load mainly depends upon the magnitude or amplitude of that load. The greater the magnitude of the alternating load, the lesser the number of cycles after which it fails. Magnitude of the load that is the basis of failure, is much less than the yield stress of the material, indicating that the mechanism of failure is different from one in which the specimen is subjected to uniaxial tension. This phenomenon is called metal fatigue, and the failure is due to initiation and then propagation of a crack within the part.

Relsilience

It is the ability of a material to store elastic energy, which is also called modulus of resilience. This property is important when selecting a material for spring manufacturing.

Stress and Strain

Stress and strain discuss in follows:

Stress (N/mm^2)

It is the resistance offered by the body to deformation

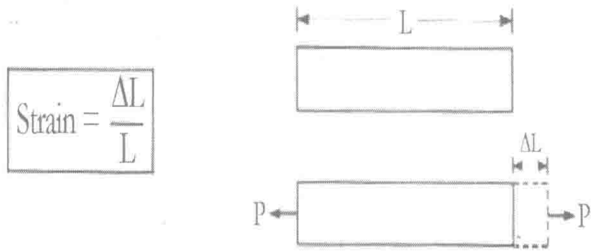
$$\text{No min al stress}\left(\text{Engineering stress}\right) = \frac{\text{Load}}{\text{Original Area}}$$

$$\text{Actual / True stress} = \frac{\text{Load}}{\text{Changed}\left(\text{Actual}\right)\text{Area}}$$

Strain

A strain is a normalized measure of deformation representing the displacement between particles in the body relative to a reference length.

Deformation per unit length in the direction of deformation is known as strain



$$\text{Strain} = \frac{\Delta L}{L}$$

Engineering Stress-Strain curve of mild steel for tension under static-loading

OA = Straight line (proportional region, Hook's law is valid)

OB = Elastic region

BD = Elasto plastic region

DE = Straight hardening

FG = Neck region

A = Limit of proportionality

B = Elastic limit

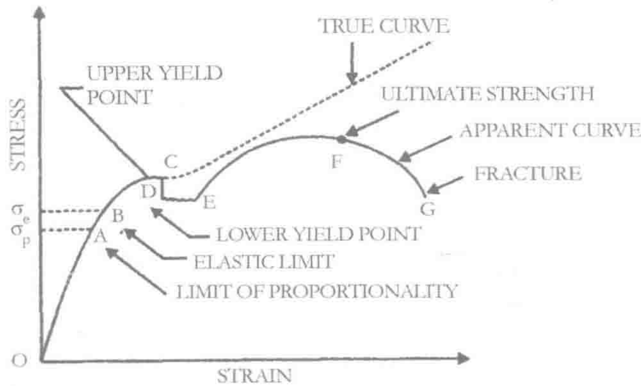
D = Lower yield point

G = Fracture point

C = Upper yield point

E = Strain hardening starts

F = Ultimate point or maximum stress point



Limit of proportionality

It is the stress at which the stress strain curve ceases to be a straight line. Hook's law is valid upto proportional limit.

Elastic Limit

It is the point on the stress strain curve upto which the material remains elastic. Upto this point there is no permanent deformation after removal of load.

Plastic Range

It is the region of the stress strain curve between the elastic limit and point of rupture.

Yield Point

This point is just beyond the elastic limit, at which the specimen undergoes an appreciable increase in length without further increase in the load.

Rupture Strength

It is the stress corresponding to the failure point G of the stress strain curve.

Proof Stress

It is the stress necessary to cause a permanent extension equals to defined percentage of gauge length.

Slope of OA = Modulus of elasticity

(Young's Modulus)

It is constant of proportionality which is defined as the intensity of stress that causes unit strain.

- Plastic strain is 10 to 15 time's elastic strain.
- Fracture strain depends on percentage of carbon steel.
- When carbon percentage increases then fracture strain decreases and yield stress increases.

Types of Tension Failure in Metal

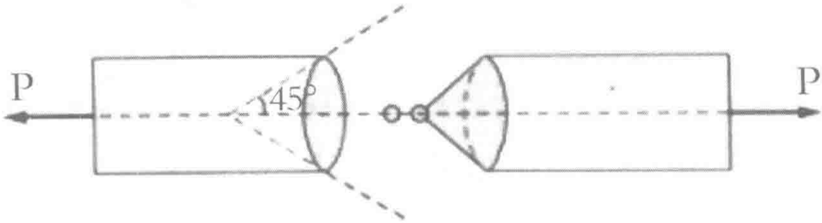
The types of tension failure in metals are follows:

- Ductile metal (Shear failure)
- Brittle metal

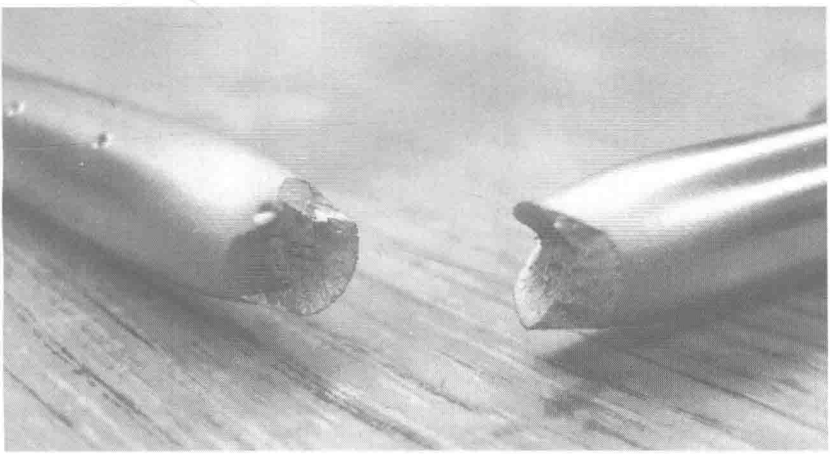
Ductile Metal (Shear Failure)

The maximum shear stress criterion, also known as Tresca's or Guest's criterion, is often used to predict the yielding of ductile materials.

Yield in ductile materials is usually caused by the slippage of crystal planes along the maximum shear stress surface.

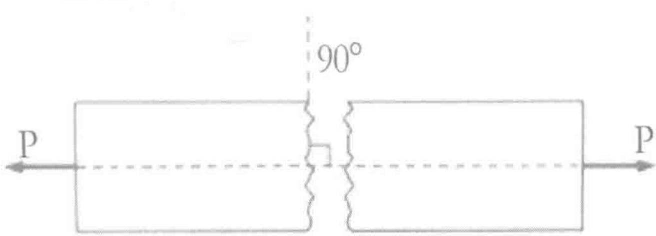


Shear strength < Tensile strength ≤ Compressive strength



Brittle Metal

A material is brittle if, when subjected to stress, it breaks without significant deformation (strain). Brittle materials absorb relatively little energy prior to fracture, even those of high strength. Breaking is often accompanied by a snapping sound. Brittle materials include most ceramics and glasses (which do not deform plastically) and some polymers, such as PMMA and polystyrene.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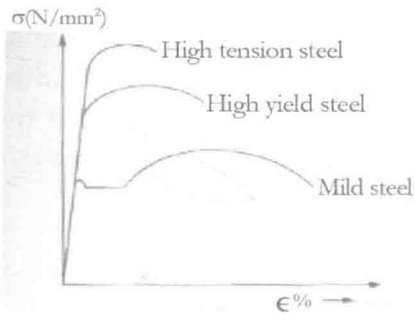
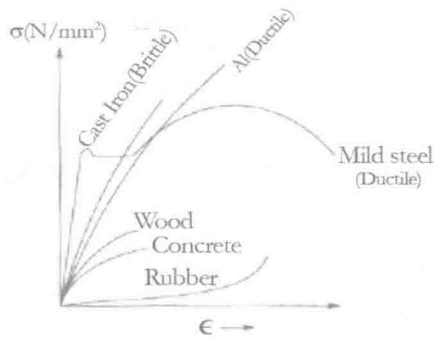
Stress-Strain Diagram for Various types of Steel/ Material

All grades of steel have same young's modulus but different yield stress.





Ductile Material

Ductile materials, which comprise structural steel, as well as may alloys of other metals, are characterized by their ability to yield at normal temperatures. As the specimen is subjected to an increasing load, its length first increases linearly with the load and at a very slow rate. Thus, the initial portion of the stress-strain diagram is a straight line with a steep slope. However, after a critical value σy of the stress has been reached, the specimen undergoes a large deformation with a relatively small increase in the applied load. This deformation is caused by slippage of the material along oblique surfaces and is due, therefore, primarily to shearing stresses.

- If post elastic straub us greater tgab 5%, it is called ductile material.
- It undergoes large permanent strains befor failure.
- Large reduction in area before fracture.

Example lead, mild steel, copper

Brittle Material

Brittle materials, which comprise cast iron, glass, and stone, are characterized by the fact that rupture occurs without any noticeable prior change in the rate of elongation. Thus, for brittle materials, there is no difference between the ultimate strength and the breaking strength. Also, the strain at the time of rupture is much smaller for brittle than for ductile materials. From the figure, note the absence of any necking of the specimen in the case of a brittle material, and observe that rupture occurs along a surface perpendicular to the load. It is concluded from this observation that normal stresses are primarily responsible for the failure of brittle materials.

Hooke's Law

When a material behaves elastically and exhibits a linear relationship between stress and strain, it is called linearly elastic. For such materials stress (σ_y) is directly proportional to strain (ε).

$$\sigma \propto \in \rightarrow \sigma = E. \in$$

$$E_{\text{cast iron}} \approx \frac{1}{2} E_{\text{steel}}$$

$$E_{\text{Alu min ium}} \approx \frac{1}{3} E_{\text{steel}}$$

Where

σ =Stress

ε =Strain

E=Young modulus of elasticity