

2. CONSTITUTION OF ALLOYS

Alloy :

It is defined as a metalloid composed of two or more elements atleast one of which is a metal.
 → The elements that make up of the alloy are called alloying elements.

Phase :

phase is defined as a physically distinct and Homogenous portion of the system. A Homogenous system comprises same composition and same physical and same chemical properties throughout its volume. i.e each point in the system represents same properties.

structure :

The term structure refers to the constitution of a metal or alloy. The structure as seen by the naked eye or low magnification (up to 30x or 40x) is called macro structure and structure which is obtained with the aid of microscope at large magnification is called microstructure.

Solid solution :

It is a simplest structure of alloy. It consist of two elements soluble in each other in solid state and exist in a single phase structure. The major element which deals its crystal structure are called solvent and other minor element is called as solute.

Types of solid solutions:

In general there are two types of solid solutions they are

(i) Substitutional solid solution

(ii) Interstitial solid solution.

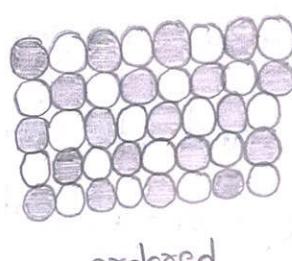
(i) Substitutional solid solution:

In substitutional solid solutions solute atoms can substitute for solvent atoms in a crystal lattice.

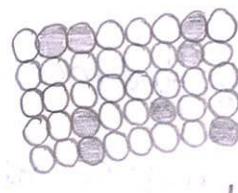
→ The crystal structure of solvent is unchanged. But the lattice may be destroyed by the presence of the solute atoms.

→ particularly if there is a significant difference in atomic diameters of the solute and solvent atoms.

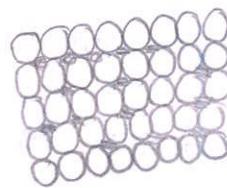
Examples: Cu-Ni, Fe-Ni, Cu-Au, Ag-Au, Pt-Ni



ordered



disordered



Interstitial

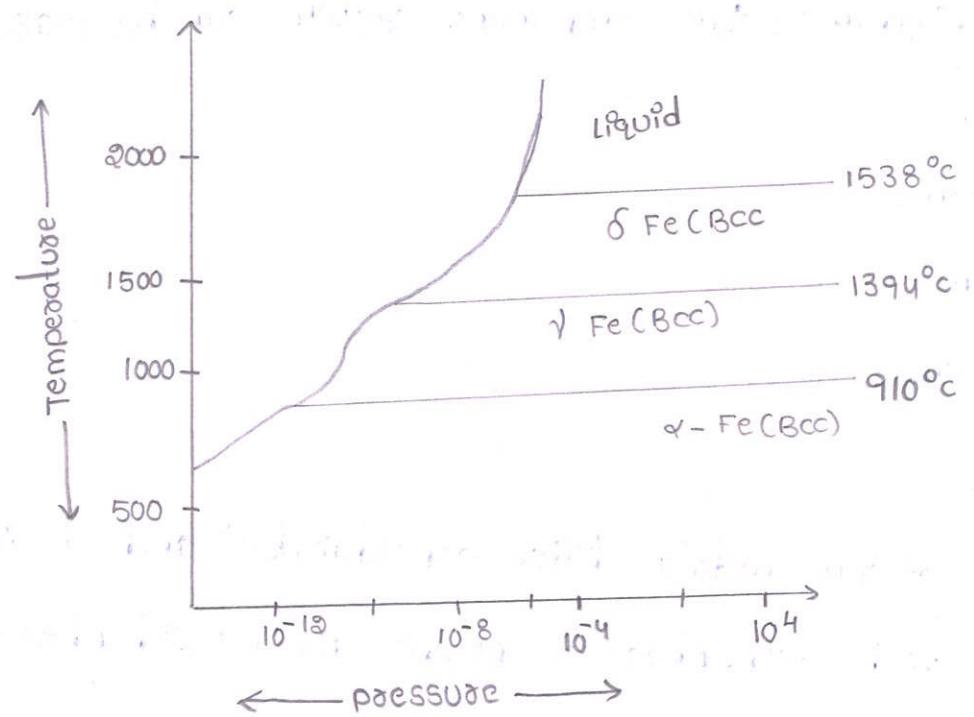
(ii) Size factors:

The diameter of the atom of the elements must not differ by more than 15% otherwise the solute atoms will create lattice distortion and new phase will form.

(iii) Electronegativity Factors:

There should be no appreciable difference in the electronegativity difference is large.

unary phase diagrams



Explain the phase diagram for pure iron.

- Any material can exist solid, liquid, vapour phases depending on the conditions are temperature, pressure and overall compositions.
- The unary phase diagram for pure iron is illustrated in above figure.
- In this case there are 3 separate and distinct solid phase. α -iron, γ -iron, and δ -iron have Bcc structure whereas γ -iron has FCC structure.

The triple point in the diagram where three different phase coexist in equilibrium are,

- 1) Liquid \rightarrow vapour and δ -iron are in equilibrium.
- 2) Vapour, δ -iron, γ -iron are in equilibrium.
- 3) Vapour - γ -iron and α -iron are in equilibrium

Binary phase diagrams:

- Different metals can combine in different ways in solid as well as liquid states.

→ depending upon the solubility characteristics of two metals, binary phase diagrams (two component system) can be classified as

(1) peritectic system.

(2) monotectic system.

(3) Eutectoid system.

(4) peritectoid system.

(1) peritectic system :

→ melting points of two metals differ considerably and a liquid phase combined with solid phase to produce new solid phase.

(2) Monotectic system :

→ In this system one liquid transforms into another liquid and one solid.

(3) Eutectoid system :

→ phase diagrams in which transformations will take place in solid state i.e. one solid decomposes into two different solids.

(4) peritectoid system :

→ Two solids reacts at constant temperature to form an other solid.

Iron - carbon equilibrium diagram

(1) allotopic forms of pure iron :

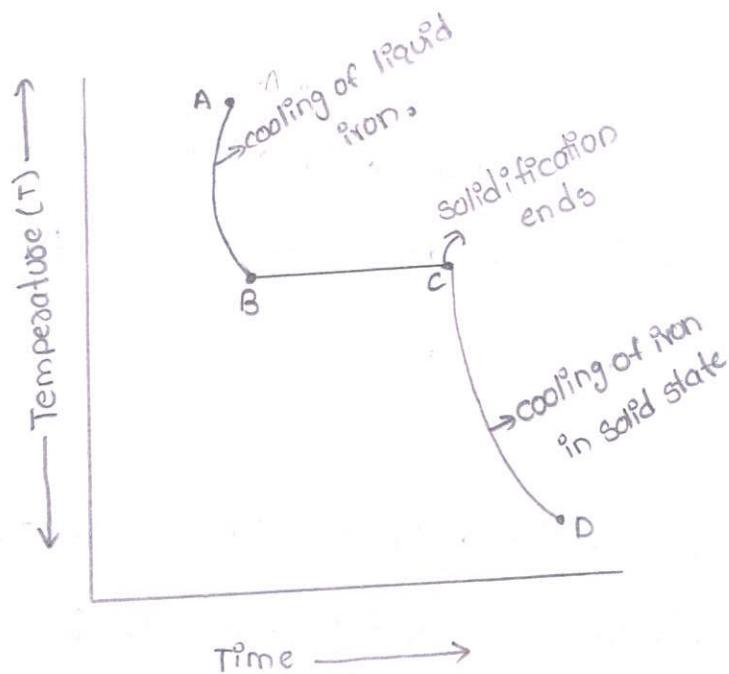
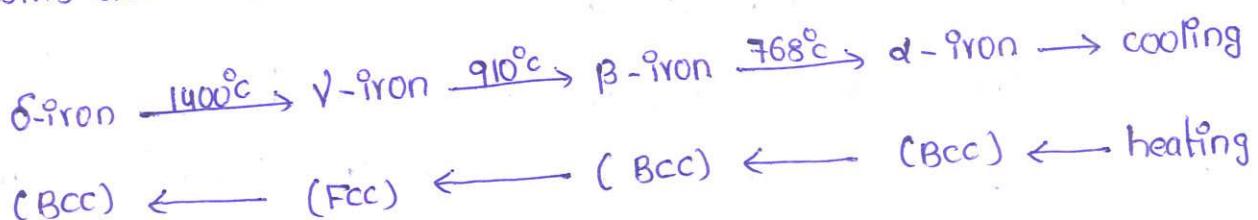
allotropy :

An element can exist in more than one crystalline form this reversible phenomenon is called allotropy.

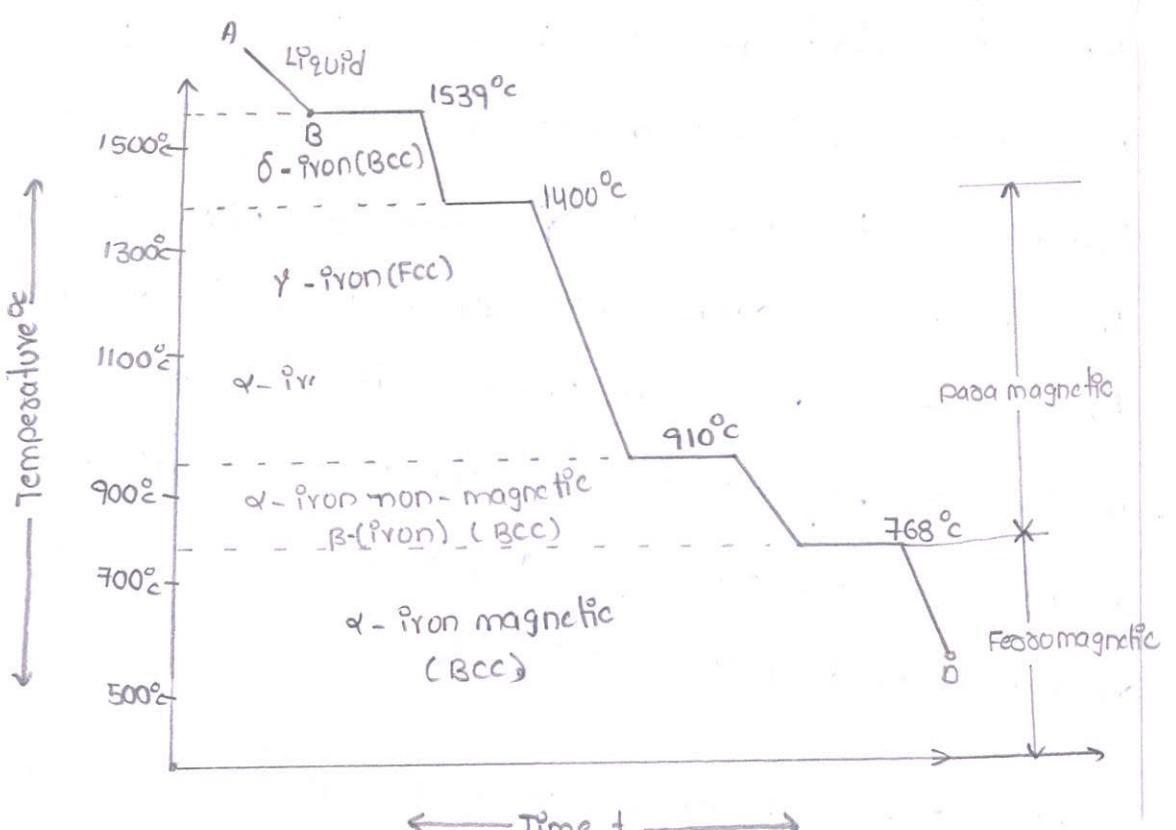
→ cooling curve for pure iron without any allotropic forms transformation from liquid to solid takes place at constant temperature.

when the latent heat of fusion is liberated. below 1539°C pure iron exist in different crystalline forms as shown in figure at 1539°C liquid iron transforms to δ (gamma) iron which has Bcc structure, and this structure is stable upto 1400°C . As cooling continued δ iron or β iron transformed to γ iron at 1400°C it has FCC structure and is non magnetic at this temperature γ -iron is transformed to α -iron if has BCC structure and its non magnetic upto 768°C .

Below 768°C α -iron is strongly magnetic α -iron between 768°C and 910°C is usually called as β -iron. These changes are reversible and same forms are observed during heating as shown in below.



with out allotropic forms.



with allotropic forms

(iii) Solid phases in Fe and Fe₃C diagram:

→ carbon atom is smaller than iron atom and dissolves in铁stitially α , γ and δ -iron in different proportions. The definitions and characteristics of solid iron and iron carbide system are briefly described below.

omega (δ) iron:

It is the interstitial solid solution of carbon in BCC crystal lattice which exist between 1400°C to 1539°C the maximum solubility of carbon at 1492°C is 0.08 %.

Ferrite (α):

It is an interstitial solid solution of carbon in α -iron (BCC crystal lattice) The maximum solubility of carbon in α -iron is 0.025 at 973°C (eutectic temperature) Ferrite is very hard and solubility of carbon decreases 0.008% at room temperature. Ferrite is very soft and ductile it is magnetic upto 768°C (curi temperature) and non magnetic above 768°C

Austenite (γ) :

The interstitial solid solution of carbon in γ -iron (Fcc) crystal lattice is called Austenite. The maximum solubility of carbon in γ -iron is 2.0% at 1130°C (Eutectic temperature) and decreases to 0.8% at 973°C . Because the FCC structure has more interstitial positions, the solid solution of carbon in Austenite is much higher than that of Ferrite. It is non-magnetic soft and ductile, but stronger than Ferrite. It has good formability.

cementite (FeC_3) :

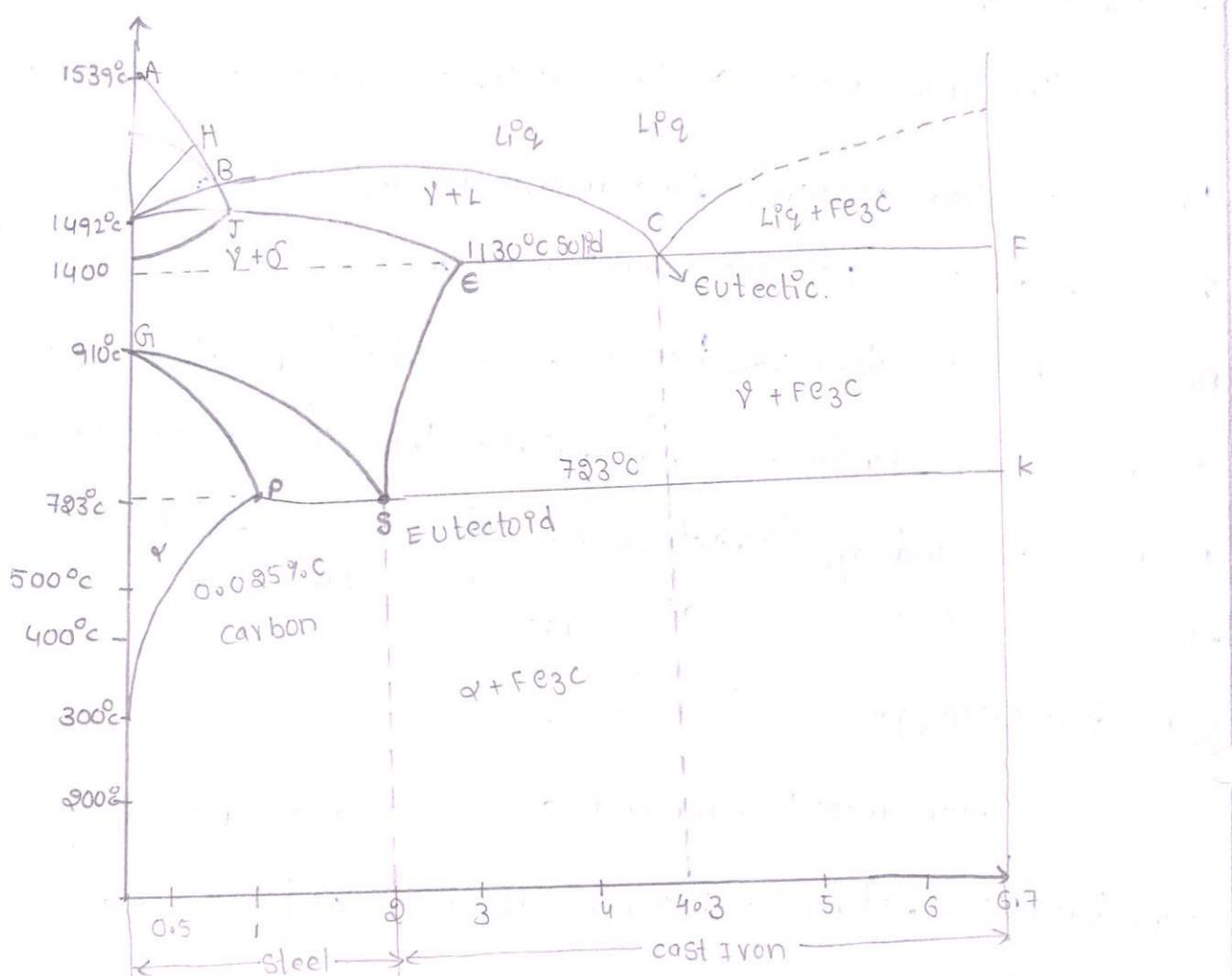
Inter metallic compound of iron or magnetite are called as cementite (FeC_3). It has orthorhombic structure. And its magnetic up to 210°C . Cementite has 6.67% carbon and is very hard and brittle and its presence has a significant influence on the properties of steel. It imparts strength and hardness to steel.

Pearlite :

The microstructure having alternate layers of Ferrite and cementite is called pearlite ($C = 0.8\%$). Pearlite can be obtained by slow cooling of Austenite at 723°C .

The mechanical properties of pearls are intermediate of ferrite (soft and ductile) Ferrite and cementite (Hard and brittle).

Based on carbon content of the iron-iron carbide diagram is divided into two parts. above 2% carbon. It is cast iron portion. Cast iron portion further subdivided into Hypotectic (carbon less than 4%) and Hyper-tectic (greater than 4.3%). Below 2% carbon it represents steel portion.

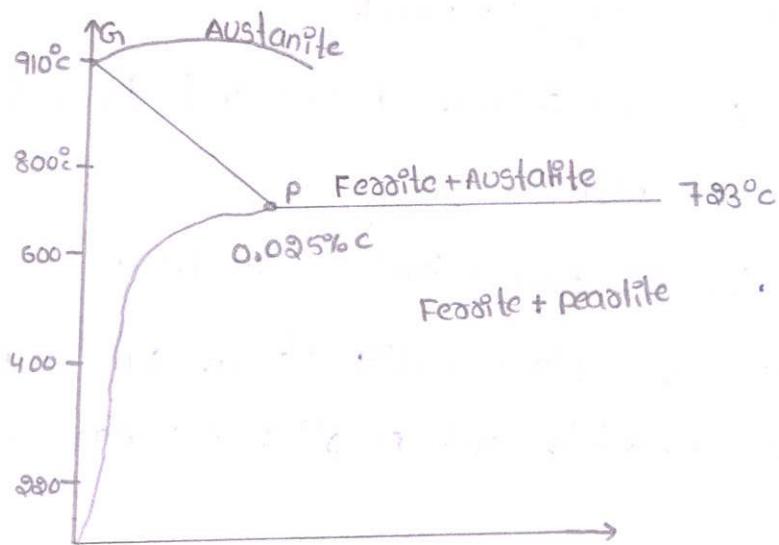
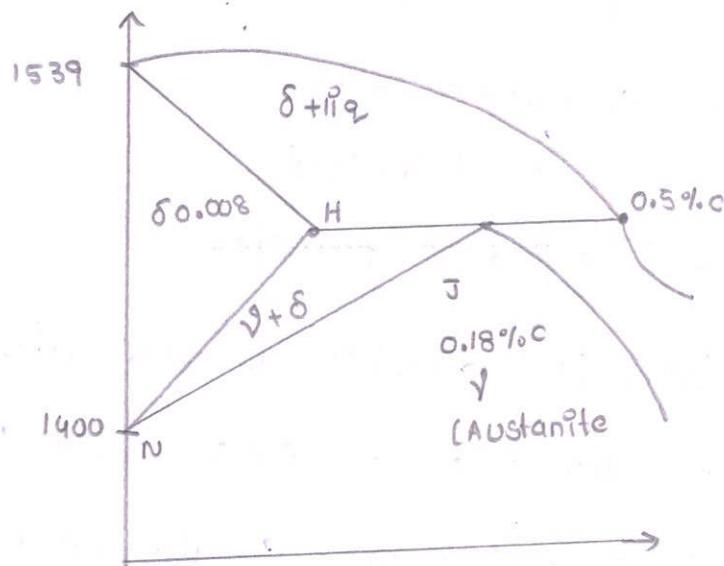


Iron-carbon phase diagram, labeled in general terms.

* Iron carbon diagram is a complex phase diagram with three invariant reactions. They are peritectic, Eutectic and Eutectoid reactions.

(i) Peritectic reactions

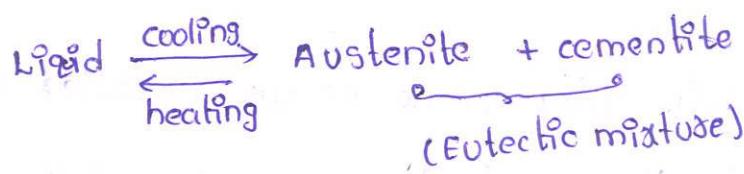
peritectic reaction occurs at 1492°C and composition of 0.18% carbon. The liquid (0.5% carbon) combines with γ -iron (0.08% carbon) to produce Austenite (0.18% carbon). This to produce Austenite (0.18% carbon) this reaction can be written as $\text{Liq} + \gamma\text{-iron} \xrightleftharpoons[\text{heating}]{\text{cooling}} \text{Austenite}$.



(2) Eutectic reactions

Eutectic reaction occurs at 1130°C and composition of 4.3% carbon

the liquid ($4.3\%\text{C}$) transforms into eutectic mixture of austenite and cementite. This reaction can be written as

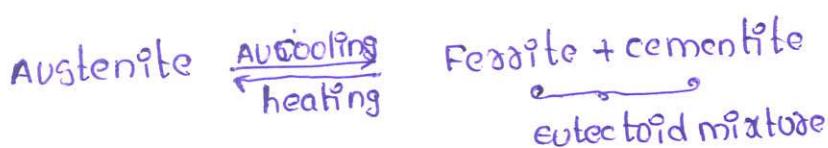


This eutectic mixture is called ledeburite.

(3) Eutectoid reaction:

This is a solid state reaction which occurs at 723°C and composition of $0.8\%\text{C}$. The Austenite ($0.8\%\text{C}$) decomposes into ferrite ($0.025\%\text{C}$)

and cementite ($6.67\% C$). This reaction written as



This Eutectoid mixture is called as pearlite.

Eutectoid reaction takes place completely in solid state. It gains much importance of the heat treatment of steel. Fig 4.4 shows the Iron-carbon diagram labelled with the common names for the structure

Micromstructure accepts of Leedburite:

- It is a mixture of $4.3\% C$ in iron and is a eutectic mixture of Austenite and cementite.
- It is not a type of steel as carbon level is too high.
- It may occurs as a separate constituent in some high carbon steels.
- mostly found with cementite and pearlite in range of cast iron.

Austenite:

- It is a solid solution of Iron-carbon which is stable only within particular range of composition and temperature.
- On cooling below $700^\circ C$ it is completely transformed into Ferrite (magnetic and cementite).

Ferrite:

Iron which contain little or no carbon is called Ferrite

- It is very soft and ductile and is known as α -iron.
- It does not harden when cooled rapidly it forms small crystals when cooled from a bright red and heated a rapid red.

Cementite :

- It is carbide of Iron (FeC_3) extremely Hard. Even Harder than hardened glass or steel
- cementite increases with the proportion of carbon present due to this cementite. It contains 6% carbon and occurs in form of network (or) globular (or) massive form. It is magnetic below 25°C
 - It presence in iron (or) steel decreases the tensile strength but increases the hardness and cutting qualities.

cast - Irons

- It is eutectic alloy of Iron and carbon. It has low melting point (1200°C). Advantageous because it can be easily melted requires less fuel and more easily operated in furnaces
- The molten metal can easily fills intricate moulds completely. These characteristics lead to an inexpensive material and versatility in product design.
- The carbon content in cast iron varies from 2% to 4.5% carbon.
- The compressive strength is much greater than its tensile strength.

