

Metals

Metals are used for various engineering purposes. They are used for making structural members, doors, windows, roofing materials, pipes and many other products. In order to find the suitability of various metals to be used for a specific work, it is essential to study their composition and properties.

Classification of metals

All the metals used in engineering works can be classified into two categories:

a. Ferrous metals

Ferrous metals are those metals in which the chief constituent is iron. Besides iron, other constituents like carbon, Sulphur, manganese and phosphorus etc. also exist in varying proportions. The ferrous metals which find their common are:

1. Cast iron
2. Wrought iron
3. Steel

b. Nonferrous metals

Nonferrous metals are those, which do not contain iron, and are used widely in building industry. The important nonferrous metals are copper, lead, tin, zinc and aluminum.

Ferrous metals

1. Cast iron

Besides iron, cast iron contains carbon, silicon, Sulphur, phosphorus and manganese in varying proportions:

Iron – 92-95%

Carbon – 2- 4.5 %

Silicon- 1-3 %

Properties:

Cast iron possesses the following important properties:

1. It has fibrous crystalline structure.
2. Brittle and has low resistance to tension and high strength in compression. Tensile and compressive strength of an average quality of cast iron are 150 N/mm^2 and 500 N/mm^2 , respectively.

3. Its melting point is about 1200 °C.
4. It cannot withstand sudden shocks.
5. Because of being brittle, it cannot be welded.
6. Its specific gravity is 7.5.
7. It cannot be magnitude.
8. It is neither malleable, nor ductile.
9. It does not rust easily.

Uses:

1. It is used for manufacture of steel and wrought iron.
2. Its high compressive strength makes it suitable for use in making such parts, which are subjected to compressive stresses such as supports of heavy machinery.
3. Since it does not rust easily, therefore it is used for parts generally exposed to atmosphere such as lampposts.
4. It is also used for making rail chairs and carriages wheels.

2. Wrought iron

It is the purest form of iron and it contains:

Iron about 98 %

Carbon – 0.1-0.25 %

Slag – 2-3 % Sulphur, manganese, phosphorus, silicon are present in traces.

Properties:

1. It has fibrous structure with a silky luster.
2. Its melting point is about 1500 °C.
3. It can withstand sudden shocks.
4. Its ultimate tensile strength is about 400 N/mm².
5. Its ultimate compressive strength is about 200 N/mm².
6. Its specific gravity is 7.25.

7. Its brinell hardness number is 105.
8. It cannot be form permanent magnets, but can be temporary magnetized.
9. It is malleable and has high ductility.
10. It can rust more easily than cast iron.
11. It softens at about 1000°C and then it can be hammered to any desired shape.

Uses:

1. It is used for making agricultural implements.
2. It is used for making rails, crane hooks and any article capable of withstand sudden loads.
3. Because it is extremely easy to weld, it is largely used in ornamental ironwork.
4. It is used as a raw material for the manufacture of steel.

3. Steel

Steel is the most important material for engineering construction. It contain carbon from 0.15 % (very soft steel) to 1.5 % (very hard steel). It also contains small amount of other elements.

It contains from:

Iron = 99 %

Carbon content – 0.15 – 1.5 %

Phosphorus and Sulphur less than 0.1 %

Manganese up to 0.5 %

Silicon up to 0.3 %

The higher is the percentage of the carbon, the harder and tougher is the steel. Depending upon the percentage of carbon contents, Steel can be classified into different groups as under:

1. Very low carbon steel – having percentage of carbon below 0.15 %.
2. Low carbon steel or mild steel –Carbon contents 0.15 – 0.3 %.
3. Medium carbon steel–Carbon contents range from 0.3 – 0.6 %.
4. High carbon steel or hard steel–Carbon contents range from 0.6 – 1.5 %.

Low carbon steel – mild steel

The percentage of carbon in mild steel varies from 0.15 to 0.3, Sulphur, phosphorus, manganese, silicon are present only in minute quantities.

Properties:

1. It has a bright dark bluish color.
2. It has fibrous structure.
3. Its melting point is about 1400 °C.
4. It can withstand sudden shocks.
5. Its tensile strength is high.
6. Its specific gravity is 7.8.
7. It is malleable, ductile and elastic.
8. It can form permanent magnets.
9. It can rust easily and rapidly.
10. It can take a good amount of compression.
11. It can easily forge and welded.

Uses:

The chief uses of mild steel are:

1. It is used for making rolled structural steel sections like girders, angle sections, channel and T- sections... etc.
2. It is extensively used for making bars and rods which are used as a reinforcing material in reinforced concrete.
3. It is used for making refrigerators and air conditioners.
4. It is used for making plain and corrugated sheets.
5. Structural mild steel is most commonly used for general construction purposes of buildings, bridges, towers and industrial buildings.
6. It also used for making tubes.

High carbon steel

These are also termed as hard steels and contain carbon varying from 0.6 to 1.5 %. Besides carbon, small percentage of Sulphur, phosphorus, manganese and silicon are also present.

Properties:

1. It has granular structure.
2. It is very hard.
3. Its specific gravity is 7.9.
4. It cannot easily forge and welded.
5. It can absorb shocks and vibrations in better way.
6. It is more elastic than mild steel.
7. It is brittle and less ductile than mild steel.
8. It rusts readily.
9. It can form permanent magnets.
10. It cannot take much of compression.

Uses:

1. It is used for parts of structures and machinery where hard, tough, elastic, shock- proof and durable material is required.
2. It is used in pre stressed concrete.
3. It is used for making knives, needles, bolts and surgical instruments.

Factors affecting physical properties of steel

1. Carbon content
 - a. The strength and hardness of steel increases as a percentage of carbon increases up to 1.5 %.
 - b. The elongation decreases as the carbon content increases and the metal becomes less resistance to impact.
 - c. The elastic range remains nearly on the same linearity, indicating that the modulus of elasticity is nearly the same and can be considered constant for various types of steel.

d. The plastic region decreases as the carbon content increases and appears to be nil for hard steel (high carbon steel).

e. The area under stress – strain curve varies with carbon content; it decreases as the percentage of carbon increases. This area represents the amount of work stored in specimen.

2. The percentage of impurities

The impurities present in steel are:

a. Silicon: If percentage of silicon is less than 0.2%, it has no appreciable effect on physical properties of steel, but when silicon content is between 0.3-0.4 %, the strength and modulus of elasticity are increased without decreasing ductility.

b. Sulphur: If Sulphur content is between 0.02-0.1 %, it has no effect on ductility and strength, but when the percentage of Sulphur is higher than 0.1%, the strength and ductility decreases.

c. Phosphorus: If the percentage of phosphorus exceed 0.12%, the strength, ductility and resistance to impact are decreased.

d. Manganese: When the manganese content is between 0.3-1 %, it helps to improving the strength of mild steel, but when it's content exceeds 1.5%, the steel becomes brittle and losses it's structural value.

3. Heat treatment: It is possible to alter the properties of steel by heating and cooling steel under controlled conditions. The term heat treatment is used to indicate the process in which the heating the heating and cooling of solid steel is involved to change the structural and physical properties of steel. The purpose of heat treatment are:

a. To alter magnetic properties of steel.

b. To change the structure of steel.

c. To increase resistance to heat and corrosion.

d. To increase surface hardness.

e. To make steel easily workable.

f. To vary strength and hardness.

Tensile requirements – ASTM – A615 – 86

Tensile requirements	Grade	
	Grade 300	Grade 400
Tensile strength, min., MPa	500	600
Yield strength, min., MPa	300	400
Elongation in 200mm, min., % For bar diameter(mm):		
10	11	9
15,20	12	9
25	-	8
30	-	7
35	-	7
45,55	-	7

Bar for grade 300 fabricated with diameter 10-20 mm only

Tensile properties – B.S. 4449-1988

Grade	Nominal size of bar mm	Specified Characteristic strength, N/mm ²	Minimum elongation of gauge length*, %
250	All sizes	250	22
460/425	6 up to and including 16 over 16	460	12
		425	14

* Gauge length is five times the diameter of the bar