6 Metals

6.1 Classification of Metals

Metals are classified into two main categories: (1) Ferrous metals which have iron as the main constituent, and (ii) Non-Ferrous metals, where in iron is not the main constituent.

Although there are many types of metals presently extracted in different parts of the world, those used in the construction industry are very few in number and have as base metals: Aluminum, Copper, Lead, Iron and Zinc.

6.2 Ferrous Metals

Iron is never found in its pure form in nature. It has to be extracted from ores, which are classed according to the iron mineral that is predominant.

Magnetite (Fe_3O_4): - Brown or steel gray to black in color, it is very hard and magnetic. It is also the richest iron ore, containing 65-75% iron when mined.

Hematite (Fe_2O_3): Another oxide of iron, red to brown in color, found in hard or soft deposits, it contains 45-65% iron.

Limonite ($Fe_2O_3 + nH_2O$): Hydrated iron or hydrated hematite is yellow in color, becomes red hematite dehydrated at high temperature. It normally contains 20-50% iron.

Siderite (Fe_2CO_3): The carbonate of iron, gray in color and usually hard and stone like contains about 30% iron.

Iron ores are sometimes classified according to their phosphorous content because this impurity cannot be removed in the blast furnace, and because it has a bad effect on the properties of iron and steel. These are: i) low phosphorous ores, containing up to about 0.04% phosphorous. They usually have a relatively high silicon content, and (ii) high phosphorous or basic ores, with up to about 2.5% phosphorous.

6.2.1 Alloys of Iron

Pure iron is a relatively soft and readily cold-worked metal. Its typical mechanical properties are:

Tensile strength = 310 MPa, Elongation in 50 mm = 35.40 %
Yield point = 207 MPa, Reduction in area = 75 %

With such high percentage elongation and reduction in area pure iron cannot be used effectively for structural purposes. In order to improve some of its properties and make it a useful and effective material, pure iron is alloyed with other chemical elements.

A large number of elements form alloys with iron. These include carbon, chromium, manganese, nickel, silicon that combined with iron, form commercially important alloys.

There are different ways of forming alloys, the two most important being (a) the method of fusion of the constituents and solidification after mixture, and (b) the method of diffusion, where the main metal is in its solid state, and the diffusing material is gas, liquid or solid. The method of fusion is the most common.

6.2.2 Steel

Alloys of iron and carbon, and at times other elements added for special purposes, make up the important classes of ferrous metals known as steel and cast iron, By varying the carbon content one can impart desired characteristics to the final product. For engineering purposes, however, only the iron-carbon system between zero and 6.67% carbon by weight is of importance in the study of steel and cast iron. The iron-carbon alloys containing from a trace to about 2% carbon with only negligible amount of other elements are called plain carbon steels. With carbon content between 2% and 6.67% the alloys are referred to as cast iron. While the iron containing a trace of carbon is referred to as soft or dead mild steel, that containing 6.67% and represented by the formula (Fe_3C) (iron carbide) is commonly called cementite. Cementite is a very hard and brittle alloy.

Plain carbon steels are elastic materials with relatively high compressive, tensile and shear strength. They are also relatively stiff having generally high modulus of elasticity.

Carbon content and ultimate tensile strength have a linear relationship. The yield point of steel in tension also increases with carbon content. The ultimate compressive strength of steel in short members not affected by column action is proportional to the carbon content up to 0.83 %.

Dead mild steel (carbon content 0.07 -0.15 %) subject to tension test will draw down and elongate extensively before rupture takes place: however this behavior changes with increasing carbon content.

The shearing strength of steel also increases with carbon content and is approximately 80% of the tensile strength for mild and medium-carbon steel, but decreases to 60% for high-carbon steel.

The ultimate strength, yield point, modulus of elasticity and hardness of steel decrease with increase in temperature. Mechanical work performed on a steel product affects its internal structure and properties. The effect on the properties depends to a certain extent on the temperature at which the mechanical work is performed, i.e., hot working or cold working.

Hot working of steel is done by hot rolling, forging, hydraulic or- mechanical pressing and extrusion. Cold working is generally done at room temperature and the properties of cold-worked steel depend on the method and amount of cold work. In general, cold working leads to a marked increase in ductility and toughness; however, extensive cold working has a marked effect on high carbon than low carbon steels.

Alloy Steels

While alloys of iron and carbon are referred to as plain carbon steels, the term alloy steels is applied to alloys of iron, carbon and one or more metallic elements, such as chromium, nickel, molybdenum, etc.

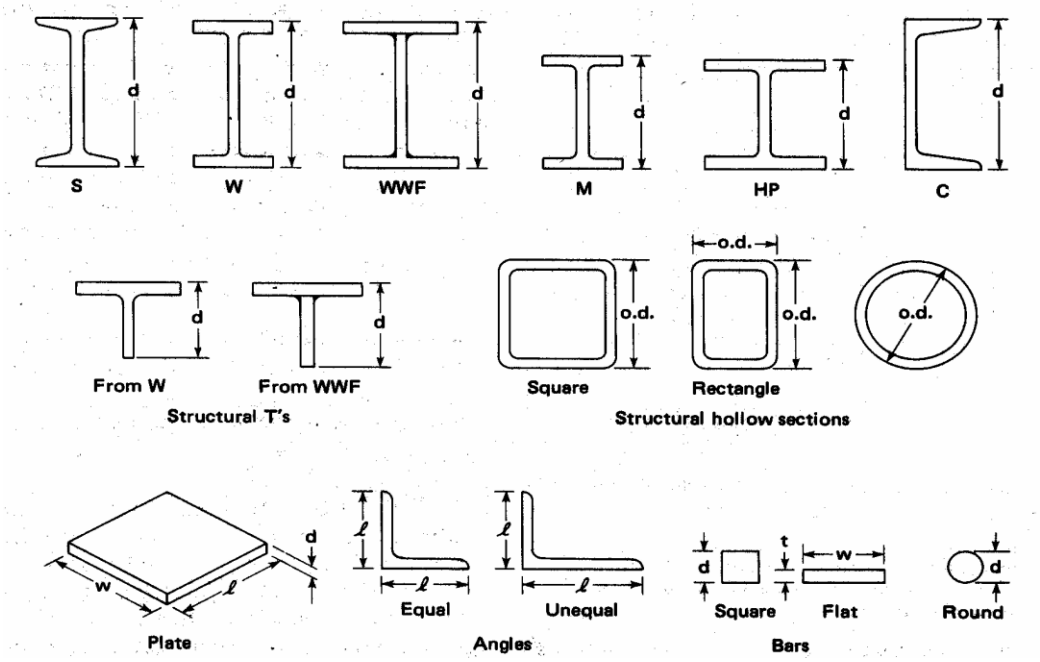
The important reason for adding alloys other than carbon is to increase the strength and hardness of the steel.

For instance, next to carbon, molybdenum is the most effective hardening element. Chromium also gives great hardness.

Nickel, silicon and tungsten increase strength. Chromium also insures increased resistance to corrosion. A combination of 18 percent chromium, 8 percent nickel and 0.07 to 0.16 percent carbons added to iron results in a particularly effective stainless steel.

6.2.3 Steel Products

Rolled and welded structural shapes are among the most important steel products used in building construction (see the figure). Steel is also used for the production of sheet piling, reinforcing steel, steel wire, nails and screws, bolts and nuts and roofing sheets.



Structural rolled and welded shapes

6.2.4 Corrosion

If left unprotected, plain carbon steel corrodes. Corrosion starts at the surface of the steel and in due course proceeds inwards and if not arrested will destroy the metal. Corrosion is the result of chemical action of plain carbon steel that goes into solution with moist air or water containing dissolved oxygen. At first contact with damp air, plain carbon steel forms a few atoms thick film of hydrogen and other products of corrosion. This film that is very thin and usually invisible has a protective effect over the surface of the metal and may retard or even stop further corrosion. If however, free oxygen is abundant it readily combines with the hydrogen film and permits further progress of corrosion. In construction, the least expensive and common method of protecting steel against corrosion is the application of one or several coats of paint over its surface.

6.3 Nonferrous Metals

Almost all nonferrous metals used in construction with the possible exceptions of copper, lead, and zinc, are alloys. Nonferrous alloys are generally classified in terms of their predominant metal; thus most aluminums are aluminum-based alloys, tins are tin-based alloys, and so on.

Aluminum

Because it is light, noncorrosive, has a good strength-to-weight ratio, easily formed and extruded, aluminum has a wide range of uses in construction. It can be formed into structural shapes, extruded into architectural shapes, and cast into variety of miscellaneous shapes.

Lead

It is a soft, plastic, malleable metal used primarily in sheet form. It is used as flashing, in curtain wall panels, and as roofing material.

Copper

Copper has been used for centuries as roofing and is still considered to be one of the most satisfactory and enduring materials for metal roofing.

Tin

Because of its resistance to corrosion, tin is used largely to coat iron and steel roofing sheets.

Zinc

Rolled sheet zinc is sometimes used for roofing and flashing, but zinc has much wider application as coating for steel roofing sheets.