1. Material for Steel Structures

Plate, sections, tube, and sometimes forgings and castings are the basic materials of steel structures. Reinforcing bar can be added to this list as it forms a major part of composite buildings.

There are many thousands of different types of steel. It is a very widely used material and many types are unsuitable for steel structures. Its other uses include motor body panels, whitegoods, furniture, cutlery, cutting and die tools, wire, rails, furnace parts, mechanical components and rocket motor casings.

1.1. Iron and Steel Manufacture

Iron in the form of iron oxides is widespread over the surface of the earth. Usually the ore is contaminated with aluminates and silicates. It may contain phosphorus, which is difficult to remove. The most widespread ore is haematite, which is predominantly Fe_2O_3, however sources of magnetite (Fe_3O_4) of high purity also exist. Carbonate ores also occur, but are of relatively low purity. In places like the Pilbara and Northern Queensland, the concentration of iron is sufficiently high to make mining economic.

1.1.1. Steel Making Methods

Pure iron only exists naturally as meteorites, which although being uncommon are the most likely source of iron used in antiquity. Iron and steel are made commercially by reducing oxide or carbonate ores. Before the blast furnace became widely used, ore lumps were heated with charcoal (carbon and wood ash) to reduce the oxide to iron. The iron does not melt during this process so heating and hammering is used to consolidate the lumps to make wrought iron.

Most ore these days is reduced to iron in a blast furnace to produce an impure material called pig iron. In this case, the reduction process uses carbon in the form of coke. Limestone is added to combine with impurities such as aluminates, silicates and phosphorus to form a liquid slag. Air is blown through the furnace to create heat required for the reduction reaction and melting the iron and slag by burning some of the coke. In the process the iron melts and collects at the bottom of the furnace. It is tapped off continuously, and is stored as molten pig iron in vessels known as torpedoes, or is cast into sand moulds as pigs.

Pig iron contains a high level of carbon, silicon and sulphur from the blast furnace charge, and has little use as a finished product. These impurities are oxidised out in the steelmaking furnace by blowing oxygen through the melted pig iron. In early days of steelmaking, air was used as an oxidising agent, but more modern processes use oxygen, sometimes diluted with argon or steam to avoid pick-up of nitrogen, to oxidise phosphorus and improve efficiency. Usually there is more than enough heat generated by the oxidation process to reheat the charge.

There are various modern steelmaking processes and treatments, all of which are batch treatments. The charge may consist of molten or cold pig iron and steel scrap, or just scrap. Electric arcs are used for heating where extra heat is required above that generated from the oxidation of the surplus carbon in pig iron. Gases are blown from the bottom of the furnace or through a lance dipped into the molten steel from the top. The furnace lining is commonly basic (calcium and magnesium carbonates or oxides), and basic slags are added to remove silicates and other acid impurities. Sometimes stirring by rotating the furnace is used. Alloy elements and deoxidants are added sometimes as pieces directly into the melt, or as powders carried by the gas in the lance.

Direct reduced iron is a method of steel manufacture that is replacing the blast furnace. In this process pelletised iron ore is reduced using hydrogen to make a spongy material known as DRI. It is not contaminated with carbon and can be efficiently turned into steel. The reducing gas is made by reacting natural gas with water in a reformer. Carbon dioxide is removed before the gas is streamed into the DRI reactor. The DRI is transformed to steel by melting in an electric arc furnace with carbon, other alloy elements and steel scrap. DRI is being increasingly used in mini mills, but the large mills produce steel most economically using the blast furnace. It is doubtful if new blast furnaces will be built because of environmental concerns. Large quantities of greenhouse gas are generated in the production of coke.

After steel making the molten steel is poured or tapped into a ladle for transport to ingot pouring or to a caster. Further processing may take place in the ladle.

1.1.2. Deoxidation and Other Ladle Treatments

Ladle treatments may be used to modify the steel where there are special requirements. Manganese is added to all steel to tie up surplus sulphur as manganese sulphide. Iron sulphide has a low melting point and steels without sufficient manganese are likely to suffer cracking during hot work or welding. An excess of manganese is a useful alloy element, strengthening the steel.

Deoxidation is the removal of surplus oxygen before the molten steel solidifies. A combination of silicon and aluminium in sufficient quantities are added to the ladle to react with surplus oxygen. The products of these reactions mostly float as slag on the surface of the melt. The resultant material is known as fully killed steel, and contains a small excess of silicon or aluminium.

Rimming steel is not deoxidised (or is un-killed). When it is cast into the ingot mould, carbon reacts with oxygen to generate carbon monoxide gas. This reaction continues during solidification, so that rimming steel ingots contain porosity. Rimming steel contains no silicon or aluminium. It has little structural application these days.

Where required, alloying with nickel, chromium, molybdenum and other alloys is done by adding these materials to the ladle. Other ladle treatments, such as desulphurisation with rare earths, or removing nitrogen with aluminium are also sometimes used. Often alloy steels are refined by bubbling with argon to remove surplus oxygen before the alloys are added.

Vacuum degassing can be used to further refine molten steel. The ladle is sealed and evacuated so that volatile impurities such as hydrogen, sulphur, lead, copper and tin boil off under a low pressure. Oxidation is prevented, allowing close control of composition. This process is commonly used in the production of alloy steels.

Electroslag refining is a method of purifying solidified steel. The steel is originally cast into an ingot of convenient shape, which is then used as an electrode in an electroslag furnace. Heat for remelting the anode is created by resistance heating of a slag. The slag has a powerful cleaning action and the resultant melt is of very high quality.

1.1.3. Ingot and Continuos Casting

Traditionally steel was cast into large ingots, which were allowed to cool before they were rolled into rod, plate or sections. Fully killed steel shrinks when ingot cast, so that the top of the ingot has to be discarded, because it contains a large shrinkage pipe. This makes fully killed ingot cast steel expensive. Rimming steel tends to froth as it solidifies. The trapped gas prevents shrinkage in the moulds, which ensures the entire ingot is useable, but the composition is not uniform and the centre of the ingot contains porosity. Semi-killed steel contains sufficient deoxidants to partially stop the rimming reaction. There is no shrinkage pipe and better uniformity than rimming steel.

Ingot casting is still used for alloy steels, which are only required in small quantities, however nearly all structural steel these days is continuously cast.

In continuous casting, the steel is removed from the bottom of the mould as it solidifies. Molten steel is added to a tundish, which maintains a constant level of liquid steel in the caster. Water spraying is used to cool the strand. It is bent using rollers while it is hot so that its travel direction changes from vertical to horizontal. Continuous casting improves productivity and consistency of composition. Only fully killed steel is continuously cast.

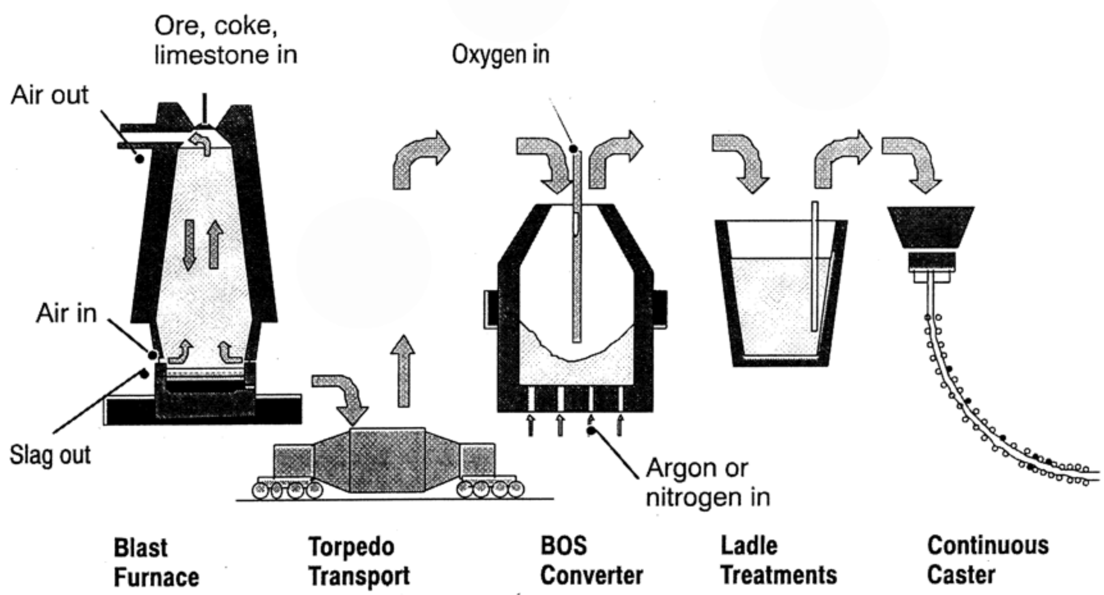

Figure 1 Structural steel making process

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by John Taylor BSc, Sen.MWeldI

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