1.4 The manufacturing of steel structures

For design of structures, the structural engineer uses long and flat products. The long products include: angles; channels; joists/beams; bars and rods; while the flat products comprise: plates; hot rolled coils (HRC) or cold rolled coils (CRC)/sheets in as annealed or galvanised condition. The starting material for the finished products is as given below:

· Blooms in case of larger diameter/cross-section long products

· Billets in case of smaller diameter/cross-section long products

· Slabs for hot rolled coils/sheets

· Hot rolled coils in case of cold rolled coils/sheets

· Hot/Cold rolled coils/sheets for cold formed sections

1.4.1 Electric arc or induction furnace route for steel making in mini or midi steel plants

The production process depends upon whether the input material to the steel plant is steel scrap or the basic raw materials i.e. iron ore. In case of former, the liquid steel is produced in Electric Arc Furnace (EAF) or Induction Furnace (IF) and cast into ingots or continuously cast into blooms/billets/slabs for further rolling into desired product. The steel mills employing this process route are generally called as mini or midi steel plants. Since liquid steel after melting contains impurities like sulphur and phosphorus beyond desirable limits and no refining is generally possible in induction furnace. The structural steel produced through this process is inferior in quality. Through refining in EAF, any desired quality (i.e. low levels of sulphur and phosphorus and of inclusion content) can be produced depending upon the intended application. Quality can be further improved by secondary refining in the ladle furnace, vacuum degassing unit or vacuum arc-degassing (VAD) unit.

1.4.2 Iron making and basic oxygen steel making in integrated steel plants

When the starting input material is iron ore, then the steel plant is generally called the integrated steel plant. In this case, firstly hot metal or liquid pig iron is produced in a vertical shaft furnace called the blast furnace (BF). Iron ore, coke (produced by carbonisation of coking coal) and limestone [Fig.] in calculated proportion are charged at the top of the blast furnace. Coke serves two purposes in the BF (Fig). Firstly it provides heat energy on combustion and secondly carbon for reduction of iron ore into iron. Limestone on decomposition at higher temperature provides lime, which combines with silica present in the iron ore to form slag. It also combines with sulphur in the coke and reduces its content in the liquid pig iron or hot metal collected at the bottom of the BF.

The hot metal contains very high level of carbon content around 4%; silicon in the range of 0.5-1.2%; manganese around 0.5%; phosphorus in the range 0.03-0.12%; and somewhat higher level of sulphur around 0.05%. Iron with this kind of composition is highly brittle and cannot be used for any practical purposes. Hot metal is charged in to steel making vessel called LD converter or the Basic Oxygen Furnace (BOF). Open-hearth process is also used in some plants, though it is gradually being phased out [Fig.]. Oxygen is blown into the liquid metal in a controlled manner, which reduces the carbon content and oxidises the impurities like silicon, manganese, and phosphorus. Lime is charged to slag off the oxidised impurities. Ferro Manganese (FeMn), Ferro Silicon (FeSi) and/or Aluminium (Al) are added in calculated amount to deoxidise the liquid steel, since oxygen present in steel will appear as oxide inclusions in the solid state, which are very harmful. Ferro alloy addition also helps to achieve the desired composition. Generally the structural steel contains: carbon in the range 0.10-0.25%; manganese in the range 0.4-1.2%; sulphur 0.025-0.050%; phosphorus 0.025-0.050% depending upon specification and end use. Some micro alloying elements can also be added to increase the strength level without affecting its weldability and impact toughness.

If the oxygen content is brought down to less than 30 parts per million (PPM), the steel is called fully killed, whereas if the oxygen content is around 150 PPM, then the steel is called semi-killed. During continuous casting, only killed steel is used. However, both semi-killed and killed steels are cast in the form of ingots. The present trend is to go in for casting of steel through continuous casting, as it improves the quality, yield as well as the productivity.

1.4.3 Casting and primary/finish rolling

Liquid steel is cast into ingots [Fig.], which after soaking at 1280-1300^{o}C in the soaking pits [Fig] are rolled in the blooming and billet mill into blooms/billets [Fig.] or in slabbing mill into slabs. The basic shapes such as ingots, cast slabs, bloom and billets are shown in Fig.. The blooms are further heated in the reheating furnaces at 1250-1280^{o}C and rolled into billets or to large structural [Fig]. The slabs after heating to similar temperature are rolled into plates in the plate mill. Even though the chemical composition of steel dictates the mechanical properties, its final mechanical properties are strongly influenced by rolling practice, finishing temperature, and cooling rate and subsequent heat treatment.

The slabs or blooms or the billets can directly be continuously cast from the liquid state and thereafter are subjected to further rolling after heating in the reheating furnaces.

In the hot rolling operation the material passes through two rolls where the gap between rolls is lower than the thickness of the input material. The material would be repeatedly passed back and forth through the same rolls several times by reducing the gap between them during each pass. Plain rolls (Fig) are used for flat products such as plate, strip and sheet, while grooved rolls (Fig.1.9) are used in the production of structural sections, rails, rounded and special shapes. The rolling process, in addition to shaping the steel into the required size, improves the mechanical properties by refining the grain size of the material.

Final rolling of structural, bars/rods and HRC/CRC or sheet product is done in respective mills. In case of cold rolled sheets/coils, the material is annealed and skin passed to provide it the necessary ductility and surface finish

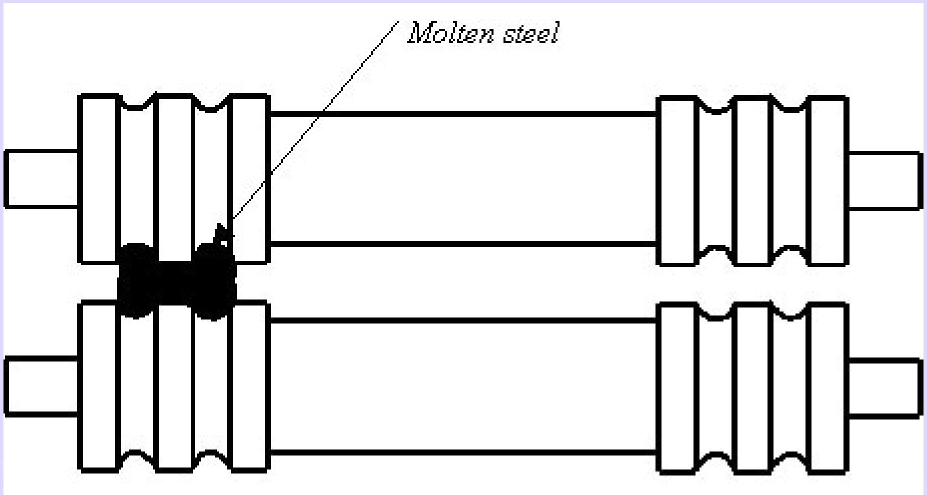

Fig 1.9. Primary rolls for structural shapes

1.4.4 Steel products and steel tables

The long products are normally used in the as-hot-rolled condition. Plates are used in hot rolled condition as well as in the normalised condition to improve their mechanical properties particularly the ductility and the impact toughness.

The structural sections produced in India include open sections such as beams, channels, tees and angles (see Fig.1.10). Closed (hollow) sections such as rectangular and circular tubes are available only in smaller sizes. Solid sections like bars, flats and strips are available. Steel plates are also available in various sizes and thicknesses. These sections are designated in a standard manner with the letters IS indicating that they satisfy the prescriptions of the Indian Standards Specifications (SP 6(1)) followed by the letter indicating the classification and type of section and a number indicating the size of the section. Usually the depth of the section is chosen to indicate its size. The beam sections are classified as ISLB (light), ISJB (junior), ISMB (medium), ISHB (heavy) and ISWB (wide-flanged) sections. Similarly, Channel sections are designated as ISLC, ISMC etc. and angles are designated as ISA followed by the size of each leg and the thickness. Both equal and unequal angles are available. Sometimes two different sections have the same designation but their weight per unit length is slightly different. In such cases, the weight per unit length is also specified as ISMB 600 @ 48.5 kg/m.

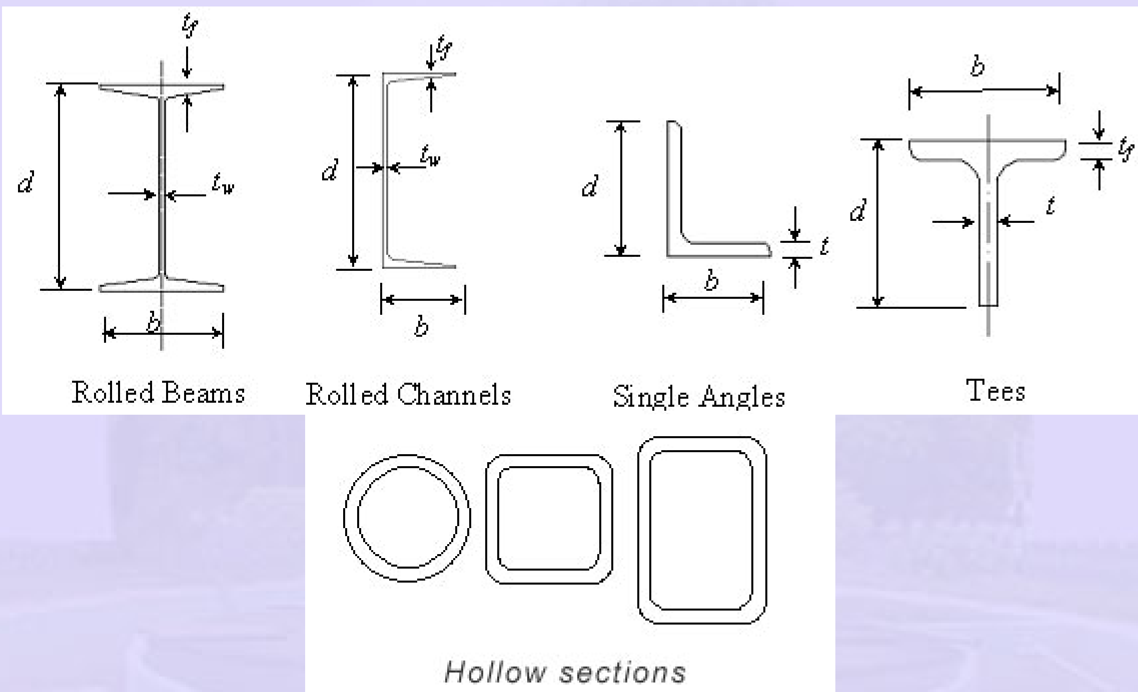

Fig 1.10 Standard shapes of rolled steel sections

The properties of sections, including the geometric details such as average thickness, area, moment of inertia about various axes and preferred location and diameter of holes for bolts etc are tabulated in the steel tables such as SP6(1). Such tables are of great use to designers for selecting a suitable section for a member.

1.4.5 Cold rolling and cold forming

Cold rolling, as the term implies involves reducing the thickness of unheated material into thin sheets by applying rolling pressure at ambient temperature. The common colds rolled products are coils and sheets. Cold rolling results in smoother surface and improved mechanical properties. Cold rolled sheets could be made as thin as 0.3 mm. Cold forming is a process by which the sheets (hot rolled / cold rolled) are folded in to desired section profile by a series of forming rolls in a continuous train of roller sets. Such thin shapes are impossible to be produced by hot rolling. The main advantage of cold-formed sheets in structural application is that any desired shape can be produced. In other words it can be tailor-made into a particular section for a desired member performance. These cold formed sheet steels are basically low carbon steels (<0.1 % carbon) and after rolling these steel are reheated to about 650 - 723oC and at this stage ferrite is recrystalised and also result in finer grain size. Because of the presence of ferrite, the ductility is enhanced. The design of cold-formed steel sections is covered by IS 801.