

Chemical Composition of Structural Steels

The primary types of structural steel are usually classified according to the following chemical composition categories:

- Carbon-manganese steels
- High-strength, low-alloy (HSLA) steels
- High-strength quenched and tempered alloy steels

The carbon-manganese steels, whose primary chemical components are carbon and manganese in addition to iron, are referred to as **carbon steels** or **mild structural steels**. The materials of this type are generally least expensive; they have quite adequate strength and ductility characteristics, and are therefore by far the most widely used grades. One of the most prominent of these steels are ASTM grade A36, with a specified minimum yield stress of *36 ksi*.

The high-strength low-alloy steels represent a relatively recent development in steelmaking. The higher strength (42 to 65 *ksi*) is achieved by adding small amounts of additional chemical elements. Two of the most common HSLA steels are ASTM grade A572 and A588.

The high-strength quenched and tempered (Q&T) alloy steels used for structural purposes are essentially available only as grade A514 today. With a yield stress level of 90 to 100 *ksi*, the increase in strength is achieved through heat treatment. A514 is available only in plate form, up to 6 inches thick.

Following is a list of some important chemical elements used in structural steels:

Carbon (C) Next to iron, carbon is by far the most important chemical element in steel. Increasing the carbon content produces a material with **higher strength** and **lower ductility**. Structural steels, therefore, have carbon contents between 0.15 to 0.30 percent; if the carbon content goes much higher, the ductility will be too low, and for magnitudes less than 0.15 percent the strength will not be satisfactory.

Manganese (Mn) Manganese appears in structural steel grades in amounts ranging from about 0.50 to 1.70 percent. It has effects similar to those of carbon, and the steel producer uses these two elements in combination to obtain a material with the desired properties. Manganese is a necessity for the process of hot rolling of steel by its combination with oxygen and sulfur.

Aluminum (Al) Aluminum is one of the most important **deoxidizers** in the material, and also helps form a more **fine-grained crystalline microstructure**. It is usually used in combination with silicon to obtain a semi- or fully killed steel.

Chromium (Cr) Chromium is present in certain structural steels in small amounts. It is primarily used to increase the **corrosion resistance** of the material, and for that reason often occurs in combination with nickel and copper. Stainless steel will typically have significant amounts of chromium. Thus, the well-known “18-8” stainless steel contains 18 percent of nickel and 8 percent of chromium.

Columbium (Cb) Columbium is a **strength-enhancing** elements, and is one of the important components in some of the HSLA steels. Its effects are similar to those of manganese and vanadium; it also has some **corrosion resistance** influence. Cb appears in types 1 and 3 of ASTM A572.

Copper (Cu) Copper is another primary **corrosion resistance** elements. It is typically found in amounts not less than 0.20 percent, and is the primary anti-corrosion component in steel grades like A242 and A441.

Molybdenum (Mo) Molybdenum has effects similar to manganese and vanadium, and is often used in combination with one or the other. It particularly increases the **strength** of the steel at **higher temperatures** and also improves **corrosion resistance**. Typical amounts of molybdenum are 0.08 to 0.25 percent for certain grades of A588 steel, and 0.15 to 0.65 percent for various types of A514.

Nickel (Ni) In addition to its favorable effect on the **corrosion resistance** of steel, nickel enhances the low-temperature behavior of the material by improving the **fracture toughness**. It is used in structural steels in varying amount; for example, certain grades of ASTM A514 have Ni contents between 0.30 and 1.50 percent; some types of A588 have nickel contents from 0.25 to 1.25 percent.

Phosphorus (P) and Sulfur (S) Both of these elements are generally **undesirable** in structural steel. Sulfur, in particular, promotes internal segregation in the steel matrix. Both act to reduce the ductility of the material. All steel grade specifications, therefore, place severe restrictions on the amount of P and S that are allowed, basically holding them to less than about 0.04 to 0.05 percent. Their detrimental effect on weldability is significant.

Silicon (Si) Along with aluminum, silicon is one of the principal **deoxidizers** for structural steel. It is the element that is most commonly used to produce semi- and fully killed steels, and normally appears in amounts less than 0.40 percent.

Vanadium (V) The effects of this chemical element are similar to those of Mn, Mo, and Cb. It helps the material develop a **finer crystalline microstructure** and gives increased **fracture toughness**. Vanadium contents of 0.02 to 0.15 percent are used in ASTM grades A572 and A588, and in amounts of 0.03 to 0.08 percent in A514.

Other chemical elements Certain steel grades utilize small amounts of other alloying elements, such as boron, nitrogen, and titanium. These elements normally work in conjunction with some of the major components to enhance certain aspects of the material performance.