WHAT ARE THE EFFECTS OF DIFFERENT ELEMENTS IN THE CHEMICAL COMPOSITION OF STEEL?

Carbon (C): Carbon is added to iron to make steel. In its pure form, iron is very soft and adding up to 2%carbon gives it toughness and strength. Structural steel plates typically contain about 0.15 to 0.3% carbon. As the amount of carbon increases in steel, the strength increases but the ductility decreases. So, iron with a lot of carbon added to it becomes very brittle and is unable to respond elastically to dynamic loading.

Silicon (Si): Silicon is added to carbon steels to help deoxidize, or *kill* them. That is, silicon helps to remove bubbles of oxygen from the molten steel. It is also useful in increasing strength and hardness but is less effective than manganese in doing so. Negatively for many uses, it also increases grain size so there is usually an upper limit on it.

Manganese (Mn): Manganese is probably the second most important alloying element after carbon in steel. Carbon has a large impact on strength, ductility and hardenability. Manganese helps to reduce oxides and also counteract the presence of iron sulfide. Steel makers, however, had to be careful that the level of carbon and manganese didn't get too high or the steel becomes too brittle and decreases weldability.

Phosphorus (P): In structural steel, phosphorus is considered to be an unwanted residual element. This is because most applications require very low or low phosphorus amounts. Phosphorus increases steel embrittlement which reduces the toughness and ductility of the metal. In uses this generally appears as cracks and fracture. High phosphorus in steel is a contributing factor to HIC cracking in wet H_2S environments.

Sulfur (S): Sulfur is another residual element in structural and pressure vessel steels. Sulfur decreases notch impact toughness, reduces weldability and decreases ductility. It generally appears as sulfide inclusions in the steel which decreases its strength.

Nitrogen (N): Nitrogen is a residual element for hot rolled steel plate. Generally, high levels of nitrogen will give the plate inconsistent mechanical properties and make welding more difficulty by increasing embrittlement in the heat affected zone (HAZ).

Copper (C): In structural steels, copper is primarily used as an alloying element as it will improve atmospheric corrosion resistance and help paint bond the steel. It also has a small impact on hardenability.

Nobium (Nb): Nobium is a key grain refining element in steel production. That is because it makes the grain size smaller, it simultaneously improves strength, toughness and ductility.

Vanadium (V): When added in the steelmaking process, vanadium helps to remove oxides and thus increases the yield strength and tensile strength of steel plates.

Titanium (Ti): Titanium in steel helps to keep grain size small and also helps manage inclusions by making them rounder.

Chromium (Cr): Chromium as an alloying element in steel helps increase its corrosion and oxidation resistance properties. When the percentage of chromium in steels exceeds 1.1%, a surface layer is formed that helps protect the steel against oxidation.

Nickel (Ni): Nickel is used to improve steel's corrosion resistance properties. It is a key component in stainless steels but at low concentrations found in carbon steels, it also helps to increase impact strength and hardenability.

Molybdenum (Mo): Molybdenum is used to increase the strength of boiler and pressure vessel steels at typical boiler operating temperatures of 400^{o}C. Typically, it is used in conjunction with chromium to provide strength and corrosion resistance at high temperature as well as increased creep strength.

Boron (B): Boron is added to fully killed fine grained steel to increase hardenability. This gives a benefit to the yield strength and toughness if the steel is fully hardened before tempering.

Zirconium (Zr): Zirconium is added to steel to modify the shape of inclusions. It helps them to become rounder (as opposed to elongated). The result is that toughness and ductility are improved when the plate is fabricated into a shell.

The following table illustrates the effects of alloying elements on the properties of steel. In this table, √ indicates that the element is advantageous with respect to the particular property, and x indicates that the element is harmful with respect to that property.

Desirabilty	Property	Carbon	Silicon	Manganese	Phosphorus	Sulfur	Nitrogen	Copper	Nobium	Vanadium	Titanium	Chromium	Nickel	Molybdenum	Boron	Zirconium	Iron
↑	Toughness	√			x	x			√				√		√	√	
↑	Strength	√	√			x			√					√			
↑	Ductility	x			x	x			√							√	
↑	Deoxidize		√	√						√		√					
↑	Hardness		√														
↓	Grain Size		x						√		√						
↑	Weldability			x		x	x										
↓	HIC Cracking				x												
↑	Mechanical Properties						x										
↓	Embrittlement				x		x										
↑	Corrosion Resistance							√				√	√				
↑	Paint Bonding							√									
↑	Yield Strength									√					√		
↑	Tensile Strength									√							
O	Inclusions										√					√	

Desirabilty	Property	Carbon	Silicon	Manganese	Phosphorus	Sulfur	Nitrogen	Copper	Nobium	Vanadium	Titanium	Chromium	Nickel	Molybdenum	Boron	Zirconium	Iron
↑	Hardenability							√					√		√		
↑	Creep Strength													√			
	Price/ Kg	24.00	2.50	1.60	300.00	500.00	5.61	8.28	180.00	14.33	8.00	9.59	54.00	30.00	11,140.00	1570.00	7.20

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