Description

Image



Caption

1. Paper clips. © Granta Design 2. Tower crane atop Mont Blanc. © Kristoferb at en.wikipedia - (CC BY-SA 3.0) 3. Girders (or beams) being placed in construction. © pkeleher at Flickr - (CC BY 2.0)

The material

Think of steel and you think of railroads, oilrigs, tankers, and skyscrapers. And what you are thinking of is not just steel, it is carbon steel. That is the metal that made them possible - nothing else is the same time so strong, so tough, so easily formed - and so cheap. Carbon steels are alloys of iron with carbon and, often a little manganese, nickel, and silicon. Low carbon or "mild" steels have the least carbon - less than 0.25%. They are relatively soft, easily rolled to plate, I-sections or rod (for reinforcing concrete) and are the cheapest of all structural metals - it is these that are used on a huge scale for reinforcement, for steel-framed buildings, ship plate and the like.

Composition (summary)

Fe/0.02 - 0.3C

General properties

Density	487	-	493	lb/ft^3
Price	* 0.29	-	0.349	USD/lb
Date first used	1610			

Mechanical properties

Young's modulus	29	-	31.2	10^6 psi
Shear modulus	11.5	-	12.2	10^6 psi
Bulk modulus	22.9	-	25.4	10^6 psi
Poisson's ratio	0.285	-	0.295	
Yield strength (elastic limit)	36.3	-	57.3	ksi
Tensile strength	50	-	84.1	ksi
Compressive strength	36.3	-	57.3	ksi
Elongation	26	-	47	% strain

Hardness - Vickers	108	-	173	HV
Fatigue strength at 10^7 cycles	* 29.4	-	42.5	ksi
Fracture toughness	* 37.3	-	74.6	ksi.in^0.5
Mechanical loss coefficient (tan delta)	* 8.9e-4	-	0.00142	

Thermal properties

Melting point	2.7e3	-	2.78e3	°F
Maximum service temperature	* 662	-	752	°F
Minimum service temperature	* -90.7	-	-36.7	°F
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	28.3	-	31.2	BTU.ft/h.ft^2.F
Specific heat capacity	0.11	-	0.121	BTU/lb.°F
Thermal expansion coefficient	6.39	-	7.22	µstrain/°F

Electrical properties

Electrical conductor or insulator?	Good conductor			
Electrical resistivity	15	-	20	µohm.cm

Optical properties

Transparency	Opaque

Critical Materials Risk

High critical material risk?	No

Processability

Castability	3		
Formability	4	-	5
Machinability	3	-	4
Weldability	5		
Solder/brazability	5		

Durability: water and aqueous solutions

Water (fresh)	Acceptable
Water (salt)	Limited use
Soils, acidic (peat)	Acceptable
Soils, alkaline (clay)	Acceptable
Wine	Unacceptable

Durability: acids

Acetic acid (10%)	Limited use
Acetic acid (glacial)	Unacceptable
Citric acid (10%)	Unacceptable

Hydrochloric acid (10%)	Unacceptable
Hydrochloric acid (36%)	Unacceptable
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	Unacceptable
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Unacceptable
Phosphoric acid (85%)	Unacceptable
Sulfuric acid (10%)	Unacceptable
Sulfuric acid (70%)	Unacceptable

Durability: alkalis

Sodium hydroxide (10%)	Excellent
Sodium hydroxide (60%)	Acceptable

Durability: fuels, oils and solvents

Amyl acetate	Excellent
Benzene	Excellent
Carbon tetrachloride	Excellent
Chloroform	Excellent
Crude oil	Excellent
Diesel oil	Excellent
Lubricating oil	Excellent
Paraffin oil (kerosene)	Excellent
Petrol (gasoline)	Excellent
Silicone fluids	Excellent
Toluene	Excellent
Turpentine	Excellent
Vegetable oils (general)	Excellent
White spirit	Excellent

Durability: alcohols, aldehydes, ketones

Acetaldehyde	Limited use
Acetone	Excellent
Ethyl alcohol (ethanol)	Acceptable
Ethylene glycol	Acceptable
Formaldehyde (40%)	Unacceptable
Glycerol	Excellent
Methyl alcohol (methanol)	Acceptable

Durability: halogens and gases

Chlorine gas (dry)	Acceptable

Fluorine (gas)	Excellent			
O2 (oxygen gas)	Limited use			
Sulfur dioxide (gas)	Acceptable			

Durability: built environments

Industrial atmosphere	Limited use
Rural atmosphere	Acceptable
Marine atmosphere	Limited use
UV radiation (sunlight)	Excellent

Durability: flammability

Flammability	Non-flammable

Durability: thermal environments

Tolerance to cryogenic temperatures	Unacceptable
Tolerance up to 150 C (302 F)	Excellent
Tolerance up to 250 C (482 F)	Excellent
Tolerance up to 450 C (842 F)	Acceptable
Tolerance up to 850 C (1562 F)	Unacceptable
Tolerance above 850 C (1562 F)	Unacceptable

Geo-economic data for principal component

Annual world production, principal component	2.26e9	ton/yr
Reserves, principal component	1.57e11	I. ton

Primary material production: energy, CO2 and water

Embodied energy, primary production	* 2.71e3	-	3e3	kcal/lb
CO2 footprint, primary production	* 1.72	-	1.9	lb/lb
Water usage	* 5.18	-	5.72	gal(US)/lb
Eco-indicator 95	83			millipoints/kg
Eco-indicator 99	106			millipoints/kg

Material processing: energy

Casting energy	* 1.19e3	-	1.32e3	kcal/lb
Extrusion, foil rolling energy	* 527	-	582	kcal/lb
Rough rolling, forging energy	* 278	-	308	kcal/lb
Wire drawing energy	* 1.89e3	-	2.09e3	kcal/lb
Metal powder forming energy	* 4.22e3	-	4.65e3	kcal/lb
Vaporization energy	* 1.18e6	-	1.3e6	kcal/lb
Coarse machining energy (per unit wt removed)	* 88.6	-	97.9	kcal/lb
Fine machining energy (per unit wt removed)	* 423	-	468	kcal/lb
Grinding energy (per unit wt removed)				

	* 794	-	879	kcal/lb
Non-conventional machining energy (per unit wt removed)	1.18e4	-	1.3e4	kcal/lb

Material processing: CO2 footprint

Casting CO2	* 0.829	-	0.916	lb/lb
Extrusion, foil rolling CO2	* 0.364	-	0.403	lb/lb
Rough rolling, forging CO2	* 0.193	-	0.213	lb/lb
Wire drawing CO2	* 1.31	-	1.45	lb/lb
Metal powder forming CO2	* 3.11	-	3.43	lb/lb
Vaporization CO2	* 815	-	901	lb/lb
Coarse machining CO2 (per unit wt removed)	* 0.0613	-	0.0678	lb/lb
Fine machining CO2 (per unit wt removed)	* 0.293	-	0.324	lb/lb
Grinding CO2 (per unit wt removed)	* 0.55	-	0.608	lb/lb
Non-conventional machining CO2 (per unit wt removed	8.15	-	9.01	lb/lb

Material recycling: energy, CO2 and recycle fraction

Recycle	✔			
Embodied energy, recycling	* 752	-	831	kcal/lb
CO2 footprint, recycling	* 0.546	-	0.603	lb/lb
Recycle fraction in current supply	40	-	44	%
Downcycle	✔			
Combust for energy recovery	✖			
Landfill	✔			
Biodegrade	✖			
Toxicity rating	Non-toxic			
A renewable resource?	✖			

Environmental notes

The production energy of steel is comparatively low - per unit weight, about a half that of polymers; per unit volume, though, twice as much. Carbon steels are easy to recycle, and the energy to do so is small.

Supporting information

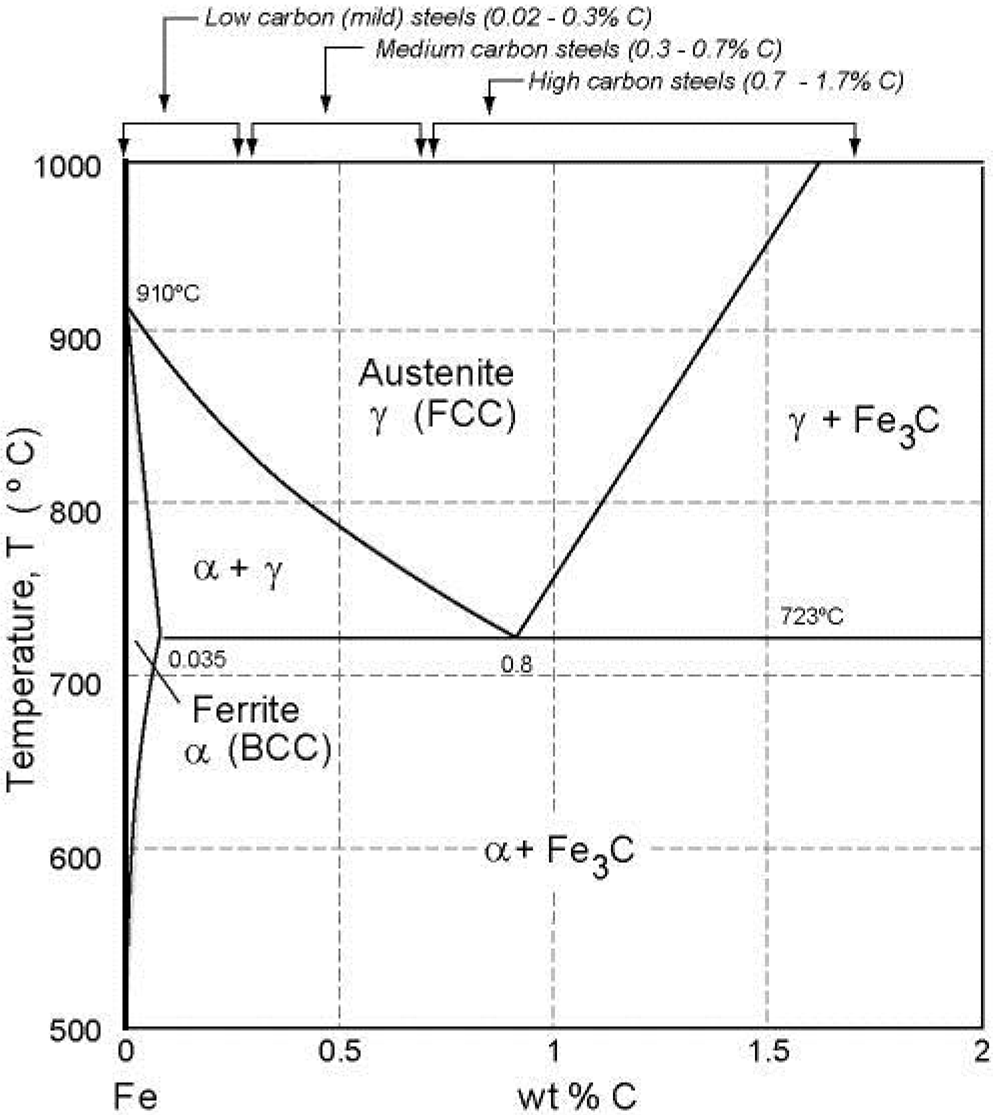
Design guidelines

Hardenability measures the degree to which it can be hardened in thick sections. Low carbon steels have too little carbon to harden much, and have poor hardenability - additional alloying elements are used to increase it (see Low alloy steels).

Technical notes

The two standard classifications for steels, the AISI and the SAE standards, have now been merged. In the SAE-AISI system, each steel has a four-digit code. The first two digits indicate the major alloying elements. The second two give the amount of carbon, in hundredths of a percent. Thus the plain carbon steels have designations starting 10xx, 11xx, 12xx or 14xxx, depending on how much manganese, sulfur and phosphorus they contain. The common low-carbon steels have the designations 1015,1020, 1022, 1117,1118; the common medium carbon steels are 1030,1040, 1050, 1060, 1137, 1141, 1144 and 1340; the common high alloy steels are 1080and 1095. More information on designations and equivalent grades can be found on the Granta Design website at www.grantadesign.com/designations

Phase diagram



Phase diagram description

Low carbon steels are alloys of iron (Fe) with 0.02 - 0.3% carbon (C), for which this is the phase diagram.

Typical uses

Low carbon steels are used so widely that no list would be complete. Reinforcement of concrete, steel sections for construction, sheet for roofing, car body panels, cans and pressed sheet products give an idea of the scope.

Links

Reference

ProcessUniverse

Producers