

## 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	7.8e3	-	7.9e3	kg/m <sup>3</sup>
Price	* 0.64	-	0.77	USD/kg
Date first used	1610			

## Mechanical properties

Young's modulus	200	-	215	GPa
Shear modulus	79	-	84	GPa
Bulk modulus	158	-	175	GPa
Poisson's ratio	0.285	-	0.295	
Yield strength (elastic limit)	250	-	395	MPa
Tensile strength	345	-	580	MPa
Compressive strength	250	-	395	MPa
Elongation	26	-	47	% strain

Hardness - Vickers	108	-	173	HV
Fatigue strength at 10 <sup>7</sup> cycles	* 203	-	293	MPa
Fracture toughness	* 41	-	82	MPa.m <sup>0.5</sup>
Mechanical loss coefficient (tan delta)	* 8.9e-4	-	0.00142	

### Thermal properties

Melting point	1.48e3	-	1.53e3	°C
Maximum service temperature	* 350	-	400	°C
Minimum service temperature	* -68.2	-	-38.2	°C
Thermal conductor or insulator?	Good conductor			
Thermal conductivity	49	-	54	W/m.°C
Specific heat capacity	460	-	505	J/kg.°C
Thermal expansion coefficient	11.5	-	13	µstrain/°C

### Electrical properties

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

### Optical properties

Transparency	Opaque			
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### Critical Materials Risk

High critical material risk?	No			
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### 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
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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
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### **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	2.3e9	tonne/yr
Reserves, principal component	1.6e11	tonne

### **Primary material production: energy, CO2 and water**

Embodied energy, primary production	* 25	-	27.7	MJ/kg
CO2 footprint, primary production	* 1.72	-	1.9	kg/kg
Water usage	* 43.2	-	47.7	l/kg
Eco-indicator 95	83			millipoints/kg
Eco-indicator 99	106			millipoints/kg

### **Material processing: energy**

Casting energy	* 11	-	12.2	MJ/kg
Extrusion, foil rolling energy	* 4.86	-	5.37	MJ/kg
Rough rolling, forging energy	* 2.57	-	2.84	MJ/kg
Wire drawing energy	* 17.4	-	19.3	MJ/kg
Metal powder forming energy	* 38.9	-	42.9	MJ/kg
Vaporization energy	* 1.09e4	-	1.2e4	MJ/kg
Coarse machining energy (per unit wt removed)	* 0.818	-	0.904	MJ/kg
Fine machining energy (per unit wt removed)	* 3.9	-	4.32	MJ/kg
Grinding energy (per unit wt removed)				

	* 7.33	-	8.11	MJ/kg
Non-conventional machining energy (per unit wt removed)	109	-	120	MJ/kg

### Material processing: CO2 footprint

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

### Material recycling: energy, CO2 and recycle fraction

Recycle	✓			
Embodied energy, recycling	* 6.94	-	7.67	MJ/kg
CO2 footprint, recycling	* 0.546	-	0.603	kg/kg
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

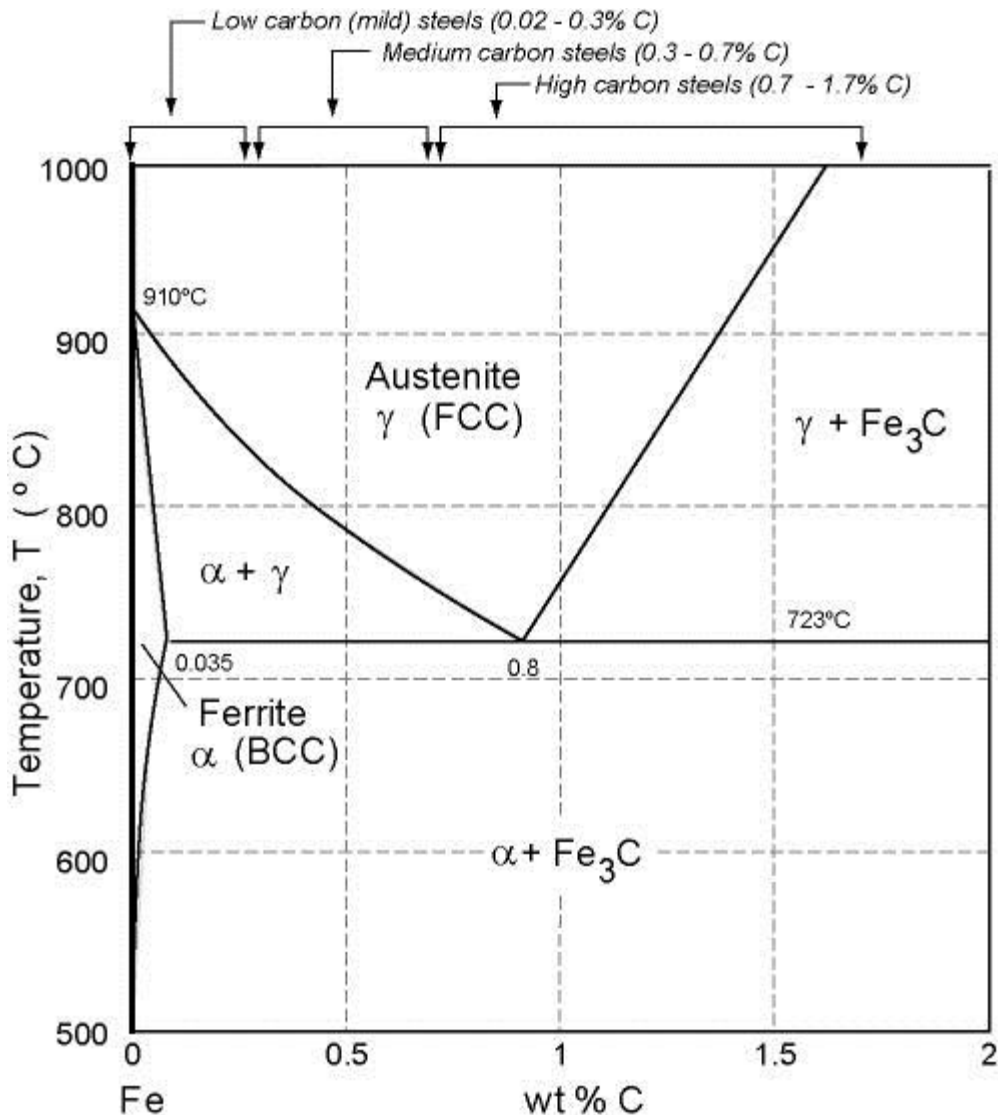
#### Design guidelines

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 1080 and 1095. More information on designations and equivalent grades can be found on the Granta Design website at [www.grantadesign.com/designations](http://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.

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## Links

Reference

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ProcessUniverse

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Producers

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