

## Description

### Image



### Caption

1. Concrete texture. © Dave Morris at Flickr - (CC BY 2.0) 2. Concrete bolcks. © iStockphoto 3. Reinforced concrete, Sydney opera house. © John Fernandez

### The material

Concrete is a composite, and a complex one. The matrix is cement; the reinforcement, a mixture of sand and gravel ('aggregate') occupying 60-80% of the volume. The aggregate increases the stiffness and strength and reduces the cost (aggregate is cheap). Concrete is strong in compression but cracks easily in tension. This is countered by adding steel reinforcement in the form of wire, mesh or bars ('rebar'), often with surface contours to key it into the concrete; reinforced concrete can carry useful loads even when the concrete is cracked. Still higher performance is gained by using steel wire reinforcement that is pre-tensioned before the concrete sets. On relaxing the tension, the wires pull the concrete into compression; the concrete does not crack until the loads applied to it overcome this compression stress ('pre-stressed concrete').

### Composition (summary)

6:1:2:4 Water:Portland cement:Fine aggregate:Coarse aggregate

## General properties

Density	144	-	162	lb/ft <sup>3</sup>
Price	* 0.0181	-	0.0272	USD/lb
Date first used	1756			

## Mechanical properties

Young's modulus	2.18	-	3.63	10 <sup>6</sup> psi
Shear modulus	* 0.943	-	1.58	10 <sup>6</sup> psi
Bulk modulus	* 1.03	-	1.73	10 <sup>6</sup> psi
Poisson's ratio	0.15	-	0.2	
Yield strength (elastic limit)	0.145	-	0.435	ksi
Tensile strength	0.145	-	0.218	ksi
Compressive strength	2.03	-	7.25	ksi
Elongation	0			% strain
Hardness - Vickers	* 5.7	-	6.3	HV
Fatigue strength at 10 <sup>7</sup> cycles	* 0.0783	-	0.122	ksi
Fracture toughness	0.319	-	0.41	ksi.in <sup>0.5</sup>
Mechanical loss coefficient (tan delta)	* 0.01	-	0.03	

## Thermal properties

Melting point	1.7e3	-	2.24e3	°F
Maximum service temperature	896	-	950	°F

Minimum service temperature	-262	-	-244	°F
Thermal conductor or insulator?	Poor insulator			
Thermal conductivity	0.462	-	1.39	BTU.ft/h.ft^2.F
Specific heat capacity	0.199	-	0.251	BTU/lb.°F
Thermal expansion coefficient	3.33	-	7.22	µstrain/°F

### Electrical properties

Electrical conductor or insulator?	Poor insulator			
Electrical resistivity	1.85e12	-	1.85e13	µohm.cm
Dielectric constant (relative permittivity)	* 8	-	12	
Dissipation factor (dielectric loss tangent)	* 0.001	-	0.01	
Dielectric strength (dielectric breakdown)	20.3	-	45.7	V/mil

### Optical properties

Transparency	Opaque			
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### Processability

Moldability	3	-	4	
Machinability	1			

### Eco properties

Embodied energy, primary production	108	-	141	kcal/lb
CO2 footprint, primary production	0.0903	-	0.0998	lb/lb
Recycle	✓			

### Supporting information

#### Design guidelines

Freshly mixed concrete is fairly fluid. Poured into wooden molds ("sets") it can be shaped to floors, walls and more elaborate structures. If they carry tension, steel reinforcement must be used; with this, more daring, slender or cantilevered structures become possible - a possibility daringly exploited by the French architect Le Corbusier, the first to realize the potential of reinforcement. Pre-stressing allows still more slender structures; the bridge in the picture is an example. Concrete, however, does not weather gracefully; unlike wood, stone and brick, it stains, discolors and cracks in a way that is visually unattractive and can expose the reinforcement to corrosive attack.

#### Technical notes

The world of concrete has developed a language of its own. Concrete is aggregate (sand plus gravel) bonded by 20-30% of Portland cement paste. Portland cement is made by calcining (heating at 1500C) a mixture of chalk and clay. They combine to give compounds of CaO ('C') and SiO2 ('S') and Fe2O3 ('F'), referred to as C3S (=3CaO.SiO2), C3A (=3CaO.Al2O3) and the like, releasing carbon dioxide. When, in powdered form, these are mixed with water they react to give hydrated compounds (C-S-H) that interlock and become solid. The reaction is slow, so the mix remains fluid enough to be cast for some hours allowing it to be transported and cast. Although the sets can be removed after 7 days, full strength is not developed for several months.

#### Typical uses

General civil engineering construction and building.

### Links

Reference

ProcessUniverse

Producers