

## Description

### Image



### Caption

1. Cement texture. © Titus Tscharntke - Public domain 2. Masonry trowel in bucket full of mortar. © Stanislaw Skowron at en.wikipedia - Public domain

### The material

We use cement and concrete in vast quantities -- quantities second only to our consumption of water. Cement is a calcined, powdered ceramic that, with the addition of water, can be molded or poured and then sets into a solid mass, bonding well to many surfaces. There are many different cements; the one most widely used construction is Portland cement, so called because the developers sought to promote it as resembling Portland stone, a layered limestone much valued for floors and pavings (the resemblance is a poor one). It is made by calcining a mixture of chalk or limestone and clay, followed by grinding to a fine powder. Mixed with water, it hydrates and sets to a hard gray solid. Portland cement can be used neat, but is more usually used as a binder with aggregates to make mortar and concrete.

### Compositional summary

63% CaO, 21% SiO<sub>2</sub>, 6% Al<sub>2</sub>O<sub>3</sub> + additions, hydrated

### General properties

Density	112	-	137	lb/ft <sup>3</sup>
Price	* 0.0454	-	0.0544	USD/lb
Date first used	-200			

### Mechanical properties

Young's modulus	* 4.38	-	6.03	10 <sup>6</sup> psi
Shear modulus	* 1.89	-	2.47	10 <sup>6</sup> psi
Bulk modulus	* 2.76	-	3.6	10 <sup>6</sup> psi
Poisson's ratio	* 0.2	-	0.24	
Yield strength (elastic limit)	* 0.276	-	0.435	ksi
Tensile strength	* 0.276	-	0.435	ksi
Compressive strength	3.48	-	3.92	ksi
Elongation	0			% strain

Hardness - Vickers	* 5.6	-	6.2	HV
Fatigue strength at 10 <sup>7</sup> cycles	* 0.131	-	0.203	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	1.71e3	-	2.19e3	°F
Maximum service temperature	1.16e3	-	1.57e3	°F
Minimum service temperature	-256	-	-238	°F
Thermal conductor or insulator?	Poor insulator			
Thermal conductivity	0.462	-	0.52	BTU.ft/h.ft <sup>2</sup> .F
Specific heat capacity	* 0.194	-	0.207	BTU/lb.°F
Thermal expansion coefficient	6.67	-	7.22	µstrain/°F

### Electrical properties

Electrical conductor or insulator?	Poor insulator			
Electrical resistivity	2e11	-	2e12	µohm.cm
Dielectric constant (relative permittivity)	* 8	-	12	
Dissipation factor (dielectric loss tangent)	* 0.001	-	0.01	
Dielectric strength (dielectric breakdown)	36.6	-	40.6	V/mil

### Optical properties

Transparency	Opaque			
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### Processability

Moldability	4	-	5	
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### Durability: water and aqueous solutions

Water (fresh)	Excellent
Water (salt)	Excellent
Soils, acidic (peat)	Acceptable
Soils, alkaline (clay)	Excellent
Wine	Excellent

### Durability: acids

Acetic acid (10%)	Acceptable
Acetic acid (glacial)	Limited use
Citric acid (10%)	Acceptable
Hydrochloric acid (10%)	Acceptable
Hydrochloric acid (36%)	Unacceptable
Hydrofluoric acid (40%)	Unacceptable
Nitric acid (10%)	

	Acceptable
Nitric acid (70%)	Unacceptable
Phosphoric acid (10%)	Acceptable
Phosphoric acid (85%)	Limited use
Sulfuric acid (10%)	Limited use
Sulfuric acid (70%)	Unacceptable

### **Durability: alkalis**

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

### **Durability: fuels, oils and solvents**

Amyl acetate	Excellent
Benzene	Excellent
Carbon tetrachloride	Excellent
Chloroform	Excellent
Crude oil	Acceptable
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	Excellent
Acetone	Excellent
Ethyl alcohol (ethanol)	Excellent
Ethylene glycol	Excellent
Formaldehyde (40%)	Excellent
Glycerol	Excellent
Methyl alcohol (methanol)	Excellent

### **Durability: halogens and gases**

Chlorine gas (dry)	Acceptable
Fluorine (gas)	Limited use
O <sub>2</sub> (oxygen gas)	Excellent
Sulfur dioxide (gas)	Acceptable

### Durability: built environments

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

### Durability: flammability

Flammability	Non-flammable
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### Durability: thermal environments

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

### Geo-economic data for principal component

Annual world production, principal component	7.38e8	-	7.48e8	ton/yr
Reserves, principal component	* 4.92e10	-	5.02e10	l. ton

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

Embodied energy, primary production	585	-	650	kcal/lb
CO2 footprint, primary production	0.906	-	1	lb/lb
Water usage	* 4.21	-	4.65	gal(US)/lb
Eco-indicator 95	20			millipoints/kg
Eco-indicator 99	15.8			millipoints/kg

### Material processing: energy

Grinding energy (per unit wt removed)	* 255	-	282	kcal/lb
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### Material processing: CO2 footprint

Grinding CO2 (per unit wt removed)	* 0.177	-	0.195	lb/lb
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### Material recycling: energy, CO2 and recycle fraction

Recycle	✗			
Recycle fraction in current supply	1	-	1.5	%
Downcycle	✓			
Combust for energy recovery	✗			
Landfill	✓			
Biodegrade	✗			
Toxicity rating	Non-toxic			

A renewable resource?



### Environmental notes

The European carbon tax hits the cement industry hard. The tax on new plant is 25 Euros per tonne of CO<sub>2</sub>, and because cement is made by calcining CaCO<sub>2</sub>, driving off CO<sub>2</sub>, and it does so by burning fuels that also generate the gas, CO<sub>2</sub> production is inevitable. A tax of 25 Euros per tonne on a product that sells for 70 Euros per tonne is a heavy burden.

## Supporting information

### Design guidelines

When water is added to cement paste, a chemical reaction starts that causes the mass to stiffen ("setting") and to develop strength ("hardening"). Portland cement reaches a compressive strength of 13 - 18 MPa after 3 days, and 24 - 27 MPa after 28 days. High alumina cement hardens more quickly, reaching up to 48 MPa in 3 days. The faster hardening cuts construction costs, but its incorrect use has led to failures. Polymers can be added to cement to increase durability and reduce permeability.

### Technical notes

Cements, clays and certain glasses are based on three main ingredients: silica (SiO<sub>2</sub>), alumina (Al<sub>2</sub>O<sub>3</sub>) and lime (CaO), sometimes with a fourth, iron oxide (Fe<sub>2</sub>O<sub>3</sub>). In cement-speak these are referred to as S, A, C and F. Thus the main constituents are reported as C<sub>3</sub>S, meaning 3(CaO).SiO<sub>2</sub>, C<sub>3</sub>A, meaning 3(CaO).Al<sub>2</sub>O<sub>3</sub>, and so on. The use of cement is covered by standard BS 12 (1958)

### Typical uses

Vast quantities of cement are used to make concrete for general civil engineering construction, where there is little exposure to sulfates in soil or groundwater. Cements are also used as mortars to cement brick, and as rendering on walls and floors.

## Links

Reference

ProcessUniverse

Producers