Cement

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.

Composition (summary)

63% CaO, 21% SiO_2, 6% Al_2O_3 + additions, hydrated

General properties

Density	1.8e3	-	2.2e3	kg/m^3
Price	* 0.1	-	0.12	USD/kg
Date first used	-200			

Mechanical properties

Young's modulus	* 30.2	-	41.6	GPa
Shear modulus	* 13	-	17	GPa
Bulk modulus	* 19	-	24.8	GPa
Poisson's ratio	* 0.2	-	0.24	
Yield strength (elastic limit)	* 1.9	-	3	MPa
Tensile strength	* 1.9	-	3	MPa
Compressive strength	24	-	27	MPa
Elongation	0			% strain

Hardness - Vickers	* 5.6	-	6.2	HV
Fatigue strength at 10^7 cycles	* 0.9	-	1.4	MPa
Fracture toughness	0.35	-	0.45	MPa.m^0.5
Mechanical loss coefficient (tan delta)	0.01	-	0.03	

Thermal properties

Melting point	930	-	1.2e3	°C
Maximum service temperature	627	-	857	°C
Minimum service temperature	-160	-	-150	°C
Thermal conductor or insulator?	Poor insulator			
Thermal conductivity	0.8	-	0.9	W/m.°C
Specific heat capacity	* 813	-	867	J/kg.°C
Thermal expansion coefficient	12	-	13	µstrain/°C

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)	1.44	-	1.6	1000000 V/m

Optical properties

Transparency	Opaque

Critical Materials Risk

High critical material risk?	No

Processability

Moldability	4	-	5

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

O2 (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			

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	7.5e8	-	7.6e8	tonne/yr
Reserves, principal component	* 5e10	-	5.1e10	tonne

Primary material production: energy, CO2 and water

Embodied energy, primary production	5.4	-	6	MJ/kg
CO2 footprint, primary production	0.906	-	1	kg/kg
Water usage	* 35.1	-	38.8	l/kg
Eco-indicator 95	20			millipoints/kg
Eco-indicator 99	15.8			millipoints/kg

Material processing: energy

Grinding energy (per unit wt removed)	* 2.35	-	2.6	MJ/kg

Material processing: CO2 footprint

Grinding CO2 (per unit wt removed)	* 0.177	-	0.195	kg/kg

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 CO2, and because cement is made by calcining CaCO2, driving off CO2, and it does so by burning fuels that also generate the gas, CO2 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 (SiO2), alumina (Al2O3) and lime (CaO), sometimes with a fourth, iron oxide (Fe2O3). In cement-speak these are referred to as S, A, C and F. Thus the main constituents are reported as C3S, meaning 3(CaO).SiO2, C3A, meaning 3(CaO).Al2O3, and so on. The used 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	