### Ministry of education and science of Ukraine

### [Lviv Polytechnic National University](http://lp.edu.ua/en)

Referan on the theme “Cement”

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Lviv 2013

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# Cement

In the most general sense of the word, a **cement** is a binder, a substance that sets and hardens independently, and can bind other materials together. The word "cement" traces to the [Romans](http://en.wikipedia.org/wiki/Ancient_Rome), who used the term [*opus caementicium*](http://en.wikipedia.org/wiki/Opus_caementicium) to describe [masonry](http://en.wikipedia.org/wiki/Masonry) resembling modern [concrete](http://en.wikipedia.org/wiki/Concrete) that was made from crushed rock with burnt [lime](http://en.wikipedia.org/wiki/Calcium_oxide) as binder. The [volcanic ash](http://en.wikipedia.org/wiki/Volcanic_ash) and pulverized [brick](http://en.wikipedia.org/wiki/Brick) additives that were added to the burnt lime to obtain a hydraulic binder were later referred to as *cementum*, *cimentum*, *cäment*, and *cement*.

Cement used in construction is characterized as **hydraulic** or **non-hydraulic**. Hydraulic cements (*e.g.,* [Portland cement](http://en.wikipedia.org/wiki/Portland_cement)) harden because of [hydration](http://en.wikipedia.org/wiki/Mineral_hydration), chemical reactions that occur independently of the mixture's water content; they can harden even underwater or when constantly exposed to wet weather. The chemical reaction that results when the [anhydrous](http://en.wikipedia.org/wiki/Anhydrous)cement powder is mixed with water produces hydrates that are not water-soluble. Non-hydraulic cements (*e.g.* [gypsum](http://en.wikipedia.org/wiki/Gypsum) [plaster](http://en.wikipedia.org/wiki/Plaster)) must be kept dry in order to retain their strength.

The most important uses of cement are as an ingredient in the production of [mortar](http://en.wikipedia.org/wiki/Mortar_(masonry)) in masonry, and of [concrete](http://en.wikipedia.org/wiki/Concrete), a combination of cement and an [aggregate](http://en.wikipedia.org/wiki/Construction_aggregate) to form a strong building material.

## History of the origin of cement

### Early uses

It is uncertain where it was first discovered that a combination of [hydrated non-hydraulic lime](http://en.wikipedia.org/wiki/Slaked_lime) and a [pozzolan](http://en.wikipedia.org/wiki/Pozzolan) produces a hydraulic mixture (see also: [Pozzolanic reaction](http://en.wikipedia.org/wiki/Pozzolanic_reaction)), but concrete made from such mixtures was first used by the [Ancient Macedonians](http://en.wikipedia.org/wiki/Ancient_Macedonians) and three centuries later on a large scale by [Roman engineers](http://en.wikipedia.org/wiki/Roman_engineering). They used both natural pozzolans ([trass](http://en.wikipedia.org/wiki/Trass) or [pumice](http://en.wikipedia.org/wiki/Pumice)) and artificial pozzolans (ground brick or pottery) in these concretes. Many excellent examples of structures made from these concretes are still standing, notably the huge [dome](http://en.wikipedia.org/wiki/Dome) of the [Pantheon](http://en.wikipedia.org/wiki/Pantheon,_Rome) in [Rome](http://en.wikipedia.org/wiki/Rome) and the massive [Baths of Caracalla](http://en.wikipedia.org/wiki/Baths_of_Caracalla). The vast system of [Roman aqueducts](http://en.wikipedia.org/wiki/Roman_aqueduct)also made extensive use of hydraulic cement.

Although any preservation of this knowledge in literary sources from the [Middle Ages](http://en.wikipedia.org/wiki/Middle_Ages) is unknown, medieval [masons](http://en.wikipedia.org/wiki/Masonry) and some military engineers maintained an active tradition of using hydraulic cement in structures such as [canals](http://en.wikipedia.org/wiki/Canal), [fortresses](http://en.wikipedia.org/wiki/Fortress), [harbors](http://en.wikipedia.org/wiki/Harbor), and [shipbuilding facilities](http://en.wikipedia.org/wiki/Shipyard). The technical knowledge of making hydraulic cement was later formalized by French and British engineers in the 18th century.

### Modern cements

Modern hydraulic cements began to be developed from the start of the [Industrial Revolution](http://en.wikipedia.org/wiki/Industrial_Revolution) (around 1800), driven by three main needs:

* Hydraulic [cement render](http://en.wikipedia.org/wiki/Cement_render) ([stucco](http://en.wikipedia.org/wiki/Stucco)) for finishing brick buildings in wet climates.
* Hydraulic mortars for masonry construction of harbor works, etc., in contact with sea water.
* Development of strong concretes.

In [Britain](http://en.wikipedia.org/wiki/Kingdom_of_Great_Britain) particularly, good quality building stone became ever more expensive during a period of rapid growth, and it became a common practice to construct prestige buildings from the new industrial bricks, and to finish them with a [stucco](http://en.wikipedia.org/wiki/Stucco) to imitate stone. Hydraulic limes were favored for this, but the need for a fast set time encouraged the development of new cements. Most famous was Parker's "[Roman cement](http://en.wikipedia.org/wiki/Roman_cement)".This was developed by [James Parker](http://en.wikipedia.org/wiki/James_Parker_(cement_maker)) in the 1780s, and finally patented in 1796. It was, in fact, nothing like any material used by the Romans, but was a "Natural cement" made by burning [septaria](http://en.wikipedia.org/wiki/Septarian_concretion) – nodules that are found in certain clay deposits, and that contain both [clay minerals](http://en.wikipedia.org/wiki/Clay_minerals) and [calcium carbonate](http://en.wikipedia.org/wiki/Calcium_carbonate). The burnt [nodules](http://en.wikipedia.org/wiki/Nodule_(geology)) were ground to a fine powder. This product, made into a mortar with sand, set in 5–15 minutes. The success of "Roman Cement" led other manufacturers to develop rival products by burning artificial mixtures of [clay](http://en.wikipedia.org/wiki/Clay) and [chalk](http://en.wikipedia.org/wiki/Chalk).

[John Smeaton](http://en.wikipedia.org/wiki/John_Smeaton) made an important contribution to the development of cements when he was planning the construction of the third[Eddystone Lighthouse](http://en.wikipedia.org/wiki/Eddystone_Lighthouse) (1755–9) in the [English Channel](http://en.wikipedia.org/wiki/English_Channel). He needed a hydraulic mortar that would set and develop some strength in the twelve hour period between successive high tides. He performed an exhaustive market research on the available hydraulic limes, visiting their production sites, and noted that the "hydraulicity" of the lime was directly related to the clay content of the [limestone](http://en.wikipedia.org/wiki/Limestone) from which it was made. Smeaton was a [civil engineer](http://en.wikipedia.org/wiki/Civil_engineer) by profession, and took the idea no further. Apparently unaware of Smeaton's work, the same principle was identified by [Louis Vicat](http://en.wikipedia.org/wiki/Louis_Vicat) in the first decade of the nineteenth century. Vicat went on to devise a method of combining chalk and clay into an intimate mixture, and, burning this, produced an "artificial cement" in 1817. [James Frost](http://en.wikipedia.org/wiki/James_Frost_(cement_maker)), working in Britain, produced what he called "British cement" in a similar manner around the same time, but did not obtain a patent until 1822. In 1824,[Joseph Aspdin](http://en.wikipedia.org/wiki/Joseph_Aspdin) patented a similar material, which he called Portland cement, because the render made from it was in color similar to the prestigious [Portland stone](http://en.wikipedia.org/wiki/Portland_stone).

Setting time and "early strength" are important characteristics of cements. Hydraulic limes, "natural" cements, and "artificial" cements all rely upon their [belite](http://en.wikipedia.org/wiki/Belite) content for [strength](http://en.wikipedia.org/wiki/Physical_strength) development. Belite develops strength slowly. Because they were burned at temperatures below 1250 °C, they contained no [alite](http://en.wikipedia.org/wiki/Alite), which is responsible for early strength in modern cements. The first cement to consistently contain alite was made by Joseph Aspdin's son [William](http://en.wikipedia.org/wiki/William_Aspdin) in the early 1840s. This was what we call today "modern" Portland cement. Because of the air of mystery with which William Aspdin surrounded his product, others (*e.g.,* Vicat and [I.C. Johnson](http://en.wikipedia.org/wiki/Isaac_Charles_Johnson)) have claimed precedence in this invention, but recent analysis of both his concrete and raw cement have shown that William Aspdin's product made at [Northfleet](http://en.wikipedia.org/wiki/Northfleet), [Kent](http://en.wikipedia.org/wiki/Kent) was a true alite-based cement. However, Aspdin's methods were "rule-of-thumb": Vicat is responsible for establishing the chemical basis of these cements, and Johnson established the importance of [sintering](http://en.wikipedia.org/wiki/Sintering) the mix in the kiln.

William Aspdin's innovation was counterintuitive for manufacturers of "artificial cements", because they required more lime in the mix (a problem for his father), a much higher kiln temperature (and therefore more fuel), and the resulting [clinker](http://en.wikipedia.org/wiki/Clinker_(cement)) was very hard and rapidly wore down the [millstones](http://en.wikipedia.org/wiki/Millstone), which were the only available grinding technology of the time. Manufacturing costs were therefore considerably higher, but the product set reasonably slowly and developed strength quickly, thus opening up a market for use in concrete. The use of concrete in construction grew rapidly from 1850 onward, and was soon the dominant use for cements. Thus Portland cement began its predominant role.

In the US the first large scale use of cement was [Rosendale cement](http://en.wikipedia.org/wiki/Rosendale_cement) a natural cement mined from a massive deposit of a large[dolostone rock](http://en.wikipedia.org/wiki/Dolostone) deposit discovered in the early 19th century near [Rosendale, New York](http://en.wikipedia.org/wiki/Rosendale,_New_York). Rosendale cement was extremely popular for the foundation of buildings (*e.g.*, [Statue of Liberty](http://en.wikipedia.org/wiki/Statue_of_Liberty), [Capitol Building](http://en.wikipedia.org/wiki/United_States_Capitol), [Brooklyn Bridge](http://en.wikipedia.org/wiki/Brooklyn_Bridge)) and lining water pipes. But its long [curing time](http://en.wikipedia.org/w/index.php?title=Curing_time&action=edit&redlink=1) of at least a month made it unpopular after World War One in the construction of highways and bridges and many states and construction firms turned to the use of Portland cement. Because of the switch to Portland cement, by the end of the 1920s of the 15 Rosendale cement companies, only one had survived. But in the early 1930s it was soon discovered that, while Portland cement had a faster setting time it was not as durable, especially for highways, to the point that some states stopped building highways and roads with cement. Bertrain H. Wait, an engineer whose company had worked on the construction of the New York Cities [Catskill Aqueduct](http://en.wikipedia.org/wiki/Catskill_Aqueduct), was impressed with the durability of Rosendale cement, and came up with a blend of both Rosendale and synthetic cements which had the good attributes of both: it was highly durable and had a much faster setting time. Mr. Wait convinced the New York Commissioner of Highways to construct an experimental section of highway near [New Paltz, New York](http://en.wikipedia.org/wiki/New_Paltz,_New_York), using one sack of Rosendale to six sacks of synthetic cement, and it was proved a success and for decades the Rosendale-synthetic cement blend became common use in highway and bridge construction.

## Types of modern cement

### Portland cement

Cement is made by heating [limestone](http://en.wikipedia.org/wiki/Limestone) (calcium carbonate) with small quantities of other materials (such as [clay](http://en.wikipedia.org/wiki/Clay)) to 1450 °C in a [kiln](http://en.wikipedia.org/wiki/Kiln), in a process known as [calcination](http://en.wikipedia.org/wiki/Calcination), whereby a molecule of [carbon dioxide](http://en.wikipedia.org/wiki/Carbon_dioxide) is liberated from the calcium carbonate to form [calcium oxide](http://en.wikipedia.org/wiki/Calcium_oxide), or quicklime, which is then blended with the other materials that have been included in the mix. The resulting hard substance, called 'clinker', is then ground with a small amount of [gypsum](http://en.wikipedia.org/wiki/Gypsum) into a powder to make 'Ordinary Portland Cement', the most commonly used type of cement (often referred to as OPC). Portland cement is a basic ingredient of [concrete](http://en.wikipedia.org/wiki/Concrete), [mortar](http://en.wikipedia.org/wiki/Mortar_(masonry)) and most non-specialty [grout](http://en.wikipedia.org/wiki/Grout). The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of [aggregate](http://en.wikipedia.org/wiki/Construction_aggregate)([gravel](http://en.wikipedia.org/wiki/Gravel) and [sand](http://en.wikipedia.org/wiki/Sand)), cement, and [water](http://en.wikipedia.org/wiki/Water). As a construction material, concrete can be cast in almost any shape desired, and once hardened, can become a structural (load bearing) element. Portland cement may be grey or white.

### Energetically Modified Cement ("EMC Cement")

An alternative fabrication technique known as EMC (Energetically Modified Cement) produces materials made from [pozzolanic minerals](http://en.wikipedia.org/wiki/Pozzolan) that have been treated using a patented milling process ("EMC Activation").The resultant [concretes](http://en.wikipedia.org/wiki/Concrete) can have the same, if not improved, physical characteristics as "normal" concretes — at a fraction of the [Portland cement](http://en.wikipedia.org/wiki/Portland_cement).

Put simply, EMC Activation is a patented, cost– and energy–efficient, near zero-emission technology for the high replacement of Portland cement in concrete.

The term "Energetically Modified Cement" is widely accepted in the academic community, first acquired in Sweden where the process was discovered in 1993 by Dr. Vladimir Ronin at [Luleå University of Technology](http://en.wikipedia.org/wiki/Lule%C3%A5_University_of_Technology) and then subsequently refined there. Although this terminology may imply that it is a "cement", it may be perhaps more accurately classified as a "[cementitious material](http://en.wikipedia.org/wiki/Cementitious)". As such, although Energetically Modified Cement is able to replace Portland cement in concrete to high levels, it cannot fully replace it.

Energetically Modified Cement is better known as "EMC Cement". EMC Cement may be classified both as an "Alternative Cementitious Material" and as a "Supplemental Cementitious Material", on account of the range of the Portland cement replacement-ratios offered. Colloquially, EMC Cement may be referred-to also as a "Green Cement", on account of the significant energy and [carbon dioxide](http://en.wikipedia.org/wiki/Carbon_dioxide) savings yielded by EMC Activation as compared to Portland cement production.

The trade name for EMC Cement is "CemPozz". At the 45th World Exhibition of Invention, Research and Innovation, held in [Bruxelles](http://en.wikipedia.org/wiki/Bruxelles), Belgium, EMC Activation was awarded the Gold Medal "with mention" by the[EUREKA](http://en.wikipedia.org/wiki/EUREKA) Organisation (the pan-European research & development funding and coordination organization, comprising all 27 [EU](http://en.wikipedia.org/wiki/EU) Member States).

Materials that are used to replace Portland cement in concrete (such as [fly ash](http://en.wikipedia.org/wiki/Fly_ash), [blast furnace slag](http://en.wikipedia.org/wiki/Blast_furnace_slag), [natural pozzolans](http://en.wikipedia.org/wiki/Pozzolana) – e.g. volcanic ash – and [silica sand](http://en.wikipedia.org/wiki/Silica_sand)) are mechanically activated in proprietary milling systems. EMC Activation increases the amount of Portland cement that can be replaced over and above "traditional" replacement methods (which typically replace an average of circa. 15% of the Portland Cement in concrete). By contrast, up to 70% of the Portland cement in concrete can be replaced using EMC Cement.

EMC Activation generates high-energy particle impacts. This leads to deep transformations in the particle micro-structure in the form of (among others) sub-micro cracks, dislocations and [lattice](http://en.wikipedia.org/wiki/Lattice_system) defects that significantly increase reactivity, with no material increase in overall powder fineness

EMC Cements comply with relevant [normative standards](http://en.wikipedia.org/wiki/Normative#Standards_documents) and specifications. For example, where EMC Cement is made from fly ash, high Portland cement replacements (i.e., the replacement of at least 50% Portland cement) yield concretes that exhibit consistent field results. This is also the case for EMC Cement made from natural pozzolans (e.g., volcanic ash).

For example, volcanic ash deposits situated in Southern California of the United States were tested by independent consultants, according to the relevant normative standards. EMC Activation was then applied to the raw materials. At 50% Portland cement replacement, the resulting concretes exceeded the normative requirements. At 28 days, the [compressive strength](http://en.wikipedia.org/wiki/Compressive_strength) was recorded at 4,180 [psi](http://en.wikipedia.org/wiki/Pounds_per_square_inch) / 28.8 [MPa](http://en.wikipedia.org/wiki/MPa) ([N](http://en.wikipedia.org/wiki/Newton_(unit))/mm²). The 56-day strength exceeded the requirements for 4,500 psi (31.1 Mpa) concrete, even taking into account the safety margin as recommended by the [American Concrete Institute](http://en.wikipedia.org/wiki/American_Concrete_Institute).

EMC Cement presents dramatic savings both in terms of carbon dioxide and energy-savings. The figures vary slightly depending on the source material used. For example, if volcanic ash is used, the resulting compound has to be dried. This drying process consumes about 150,000 [Btu](http://en.wikipedia.org/wiki/Btu) (43.96 [KWh](http://en.wikipedia.org/wiki/KWh)) per [ton](http://en.wikipedia.org/wiki/Short_ton) of EMC Cement produced.

All in all, as compared to a total energy consumption of ~1,000 to 1,400 KWh for each ton of Portland cement produced:

* For each ton of EMC Cement made from fly ash, the energy requirement is usually ~25 KWh. There are no direct CO2 emissions.
* For each ton EMC Cement made from volcanic ash, the energy requirement (including drying, as above) is no more than ~80KWh, with direct emissions of only 8 kgs CO2 per ton.

The performance of concretes made from EMC Cement can also be custom designed. Hence, concretes can range from those exhibiting superior strength and durability that reduce the [carbon footprint](http://en.wikipedia.org/wiki/Carbon_footprint) at up to ~70% as compared to concretes made from Portland Cement, through to the production of rapid and ultra-rapid hardening, [high-strength concretes](http://en.wikipedia.org/wiki/Types_of_concrete#High-strength_concrete) (for example, over 70 MPa / 10,150 psi in 24 hours and over 200 MPa / 29,000 psi in 28 days). This allows EMC Cement to yield [High Performance Concretes](http://en.wikipedia.org/wiki/Types_of_concrete#High-performance_concrete) (HPCs).

EMC Cement exhibits a high resistance to [chloride](http://en.wikipedia.org/wiki/Chloride) and [sulfate](http://en.wikipedia.org/wiki/Sulfate) ion attack, together with a low [Alkali–Silica Reactivity](http://en.wikipedia.org/wiki/Alkali%E2%80%93silica_reaction) (ASR). These features allow concretes made from EMC Cement to exhibit superior durabilities as compared to concretes made from Portland cement. For example, an early project using EMC Cement was the construction of a road bridge in [Karungi](http://en.wikipedia.org/wiki/Karungi), Sweden, with Swedish construction firm [Skanska](http://en.wikipedia.org/wiki/Skanska). The Karungi road bridge has successfully withstood the tests of time, despite Karungi's harsh [subarctic climate](http://en.wikipedia.org/wiki/Subarctic_climate) and extremely divergent annual and [diurnal](http://en.wikipedia.org/wiki/Diurnal_cycle) temperature ranges.

EMC Activation and EMC Cements are well-proven to an "industrial scale". In the United States, EMC Cement has been approved for usage by [PennDOT](http://en.wikipedia.org/wiki/PennDOT) (Pennsylvania Department of Transportation), [TxDOT](http://en.wikipedia.org/wiki/TxDOT) (Texas Department of Transportation) and [CalTrans](http://en.wikipedia.org/wiki/CalTrans) (California Department of Transportation). As a result, hundreds of miles of highway paving have been laid, together with assorted highway bridges, using concretes made from EMC Cement — including large sections of [Interstate 10](http://en.wikipedia.org/wiki/Interstate_10), which is the main U.S. Interstate highway linking[Miami](http://en.wikipedia.org/wiki/Miami), Florida with [Los Angeles](http://en.wikipedia.org/wiki/Los_Angeles), California.

Another notable project in the United States includes the extension of the passenger terminals at the [Port of Houston](http://en.wikipedia.org/wiki/Port_of_Houston), Texas. This project fully exploits EMC Cement's known propensity to yield concretes that exhibit high-resistances to chloride– and sulfate–ion permeability (i.e., increased resistance to [sea waters](http://en.wikipedia.org/wiki/Seawater)), as compared to concretes made from Portland cement.

### Portland cement blends

Portland cement blends are often available as inter-ground mixtures from cement producers, but similar formulations are often also mixed from the ground components at the concrete mixing plant. **Portland blastfurnace cement** contains up to 70% [ground granulated blast furnace slag](http://en.wikipedia.org/wiki/Ground_granulated_blast_furnace_slag), with the rest Portland clinker and a little gypsum. All compositions produce high ultimate strength, but as slag content is increased, early strength is reduced, while sulfate resistance increases and heat evolution diminishes. Used as an economic alternative to Portland sulfate-resisting and low-heat cements. **Portland flyash cement** contains up to 35% [fly ash](http://en.wikipedia.org/wiki/Fly_ash). The fly ash is [pozzolanic](http://en.wikipedia.org/wiki/Pozzolanic), so that ultimate strength is maintained. Because fly ash addition allows a lower concrete water content, early strength can also be maintained. Where good quality cheap fly ash is available, this can be an economic alternative to ordinary Portland cement. **Portland pozzolan cement** includes fly ash cement, since fly ash is a [pozzolan](http://en.wikipedia.org/wiki/Pozzolan), but also includes cements made from other natural or artificial pozzolans. In countries where [volcanic ashes](http://en.wikipedia.org/wiki/Volcanic_ash) are available (e.g. [Italy](http://en.wikipedia.org/wiki/Italy), [Chile](http://en.wikipedia.org/wiki/Chile), [Mexico](http://en.wikipedia.org/wiki/Mexico), the [Philippines](http://en.wikipedia.org/wiki/Philippines)) these cements are often the most common form in use. **Portland silica fume cement**. Addition of [silica fume](http://en.wikipedia.org/wiki/Silica_fume) can yield exceptionally high strengths, and cements containing 5–20% silica fume are occasionally produced. However, silica fume is more usually added to Portland cement at the concrete mixer. **Masonry cements** are used for preparing bricklaying [mortars](http://en.wikipedia.org/wiki/Mortar_(masonry)) and [stuccos](http://en.wikipedia.org/wiki/Stuccos), and must not be used in concrete. They are usually complex proprietary formulations containing Portland clinker and a number of other ingredients that may include limestone, hydrated lime, [air entrainers](http://en.wikipedia.org/w/index.php?title=Air_entrainer&action=edit&redlink=1), retarders, waterproofers and coloring agents. They are formulated to yield workable mortars that allow rapid and consistent masonry work. Subtle variations of Masonry cement in the US are Plastic Cements and [Stucco Cements](http://en.wikipedia.org/w/index.php?title=Stucco_Cement&action=edit&redlink=1). These are designed to produce controlled bond with masonry blocks. **Expansive cements** contain, in addition to Portland clinker, expansive clinkers (usually sulfoaluminate clinkers), and are designed to offset the effects of drying shrinkage that is normally encountered with hydraulic cements. This allows large floor slabs (up to 60 m square) to be prepared without contraction joints. **White blended cements** may be made using white clinker and white supplementary materials such as high-purity [metakaolin](http://en.wikipedia.org/wiki/Metakaolin).**Colored cements** are used for decorative purposes. In some standards, the addition of pigments to produce "colored Portland cement" is allowed. In other standards (e.g. ASTM), pigments are not allowed constituents of Portland cement, and colored cements are sold as "blended hydraulic cements". **Very finely ground cements** are made from mixtures of cement with sand or with slag or other pozzolan type minerals that are extremely finely ground together. Such cements can have the same physical characteristics as normal cement but with 50% less cement particularly due to their increased surface area for the chemical reaction. Even with intensive grinding they can use up to 50% less energy to fabricate than ordinary Portland cements.

### Non-Portland hydraulic cements

**Pozzolan-lime cements.** Mixtures of ground [pozzolan](http://en.wikipedia.org/wiki/Pozzolanic_ash) and [lime](http://en.wikipedia.org/wiki/Agricultural_lime) are the cements used by the Romans, and can be found in Roman structures still standing (e.g. the [Pantheon](http://en.wikipedia.org/wiki/Pantheon,_Rome) in Rome). They develop strength slowly, but their ultimate strength can be very high. The hydration products that produce strength are essentially the same as those produced by Portland cement. **Slag-lime cements.**[Ground granulated blast furnace slag](http://en.wikipedia.org/wiki/Ground_granulated_blast_furnace_slag) is not hydraulic on its own, but is "activated" by addition of alkalis, most economically using lime. They are similar to pozzolan lime cements in their properties. Only granulated slag (i.e. water-quenched, glassy slag) is effective as a cement component. **Supersulfated cements.** These contain about 80% ground granulated blast furnace slag, 15% [gypsum](http://en.wikipedia.org/wiki/Gypsum) or[anhydrite](http://en.wikipedia.org/wiki/Anhydrite) and a little Portland clinker or lime as an activator. They produce strength by formation of [ettringite](http://en.wikipedia.org/wiki/Ettringite), with strength growth similar to a slow Portland cement. They exhibit good resistance to aggressive agents, including sulfate. [**Calcium aluminate cements**](http://en.wikipedia.org/wiki/Calcium_aluminate_cements)are hydraulic cements made primarily from [limestone](http://en.wikipedia.org/wiki/Limestone) and [bauxite](http://en.wikipedia.org/wiki/Bauxite). The active ingredients are monocalcium aluminate CaAl2O4 (CaO · Al2O3 or CA in [Cement chemist notation](http://en.wikipedia.org/wiki/Cement_chemist_notation), CCN) and [mayenite](http://en.wikipedia.org/wiki/Mayenite) Ca12Al14O33 (12 CaO · 7 Al2O3, or C12A7 in CCN). Strength forms by hydration to calcium aluminate hydrates. They are well-adapted for use in refractory (high-temperature resistant) concretes, e.g. for furnace linings. **Calcium sulfoaluminate cements** are made from clinkers that include [ye'elimite](http://en.wikipedia.org/wiki/Ye%27elimite) (Ca4(AlO2)6SO4 or C4A3S in [Cement chemist's notation](http://en.wikipedia.org/wiki/Cement_chemist_notation)) as a primary phase. They are used in expansive cements, in ultra-high early strength cements, and in "low-energy" cements. Hydration produces ettringite, and specialized physical properties (such as expansion or rapid reaction) are obtained by adjustment of the availability of calcium and sulfate ions. Their use as a low-energy alternative to Portland cement has been pioneered in China, where several million tonnes per year are produced. Energy requirements are lower because of the lower kiln temperatures required for reaction, and the lower amount of limestone (which must be endothermically decarbonated) in the mix. In addition, the lower limestone content and lower fuel consumption leads to a CO2 emission around half that associated with Portland clinker. However, SO2 emissions are usually significantly higher. **"Natural" cements** correspond to certain cements of the pre-Portland era, produced by burning [argillaceous limestones](http://en.wikipedia.org/wiki/Argillaceous_minerals) at moderate temperatures. The level of clay components in the limestone (around 30–35%) is such that large amounts of [belite](http://en.wikipedia.org/wiki/Belite) (the low-early strength, high-late strength mineral in Portland cement) are formed without the formation of excessive amounts of free lime. As with any natural material, such cements have highly variable properties. [**Geopolymer**](http://en.wikipedia.org/wiki/Geopolymers)**cements** are made from mixtures of water-soluble alkali metal silicates and aluminosilicate mineral powders such as [fly ash](http://en.wikipedia.org/wiki/Fly_ash) and[metakaolin](http://en.wikipedia.org/wiki/Metakaolin).

## Curing (Setting)

Cement sets or cures when mixed with water which causes a series of hydration chemical reactions. The constituents slowly hydrate and crystallize; the interlocking of the crystals gives cement its strength. Maintaining a high moisture content in cement during curing increases both the speed of curing, and its final strength. [Gypsum](http://en.wikipedia.org/wiki/Gypsum) is often added to [Portland cement](http://en.wikipedia.org/wiki/Portland_cement) to prevent early hardening or "flash setting", allowing a longer working time. The time it takes for cement to cure varies depending on the mixture and environmental conditions; initial hardening can occur in as little as twenty minutes, while full cure can take over a month. Cement typically cures to the extent that it can be put into service within 24 hours to a week.

## [[edit](http://en.wikipedia.org/w/index.php?title=Cement&action=edit&section=10)]Safety issues

Bags of cement routinely have health and safety warnings printed on them because not only is cement highly [alkaline](http://en.wikipedia.org/wiki/Alkali), but the setting process is [exothermic](http://en.wikipedia.org/wiki/Exothermic). As a result, wet cement is strongly [caustic](http://en.wikipedia.org/wiki/Causticity) and can easily cause severe [skin burns](http://en.wikipedia.org/wiki/Skin_burn) if not promptly washed off with water. Similarly, dry cement powder in contact with [mucous membranes](http://en.wikipedia.org/wiki/Mucous_membrane) can cause severe eye or respiratory irritation. Cement users should wear protective clothing.

## Cement industry in the world

In 2010, the world production of hydraulic cement was 3,300 million tonnes. The top three producers were China with 1,800, India with 220, and USA with 63.5 million tonnes for a combined total of over half the world total by the world's three most populated states.

For the world capacity to produce cement in 2010, the situation was similar with the top three states (China, India, and USA) accounting for just under half the world total capacity.

### China

"For the past 18 years, China consistently has produced more cement than any other country in the world. (However,) China's cement export peaked in 1994 with 11 million tonnes shipped out and has been in steady decline ever since. Only 5.18 million tonnes were exported out of China in 2002. Offered at $34 a ton, Chinese cement is pricing itself out of the market as Thailand is asking as little as $20 for the same quality."

In 2006, it was estimated that China manufactured 1.235 billion tonnes of cement, which was 44% of the world total cement production. "Demand for cement in China is expected to advance 5.4% annually and exceed 1 billion tonnes in 2008, driven by slowing but healthy growth in construction expenditures. Cement consumed in China will amount to 44% of global demand, and China will remain the world's largest national consumer of cement by a large margin."

In 2010, 3.3 billion tonnes of cement was consumed globally. Of this, China accounted for 1.8 billion tonnes.

### Africa

## Environmental impacts

Cement manufacture causes environmental impacts at all stages of the process. These include emissions of airborne pollution in the form of dust, gases, noise and vibration when operating machinery and during blasting in [quarries](http://en.wikipedia.org/wiki/Quarry), and damage to countryside from quarrying. Equipment to reduce dust emissions during quarrying and manufacture of cement is widely used, and equipment to trap and separate exhaust gases are coming into increased use. Environmental protection also includes the re-integration of quarries into the countryside after they have been closed down by returning them to nature or re-cultivating them.

### CO2 emissions

Carbon concentration in cement spans from ≈5% in cement structures to ≈8% in the case of roads in cement. Cement manufacturing releases CO2 in the atmosphere both directly when [calcium carbonate](http://en.wikipedia.org/wiki/Calcium_carbonate) is heated, producing [lime](http://en.wikipedia.org/wiki/Lime_(mineral)) and [carbon dioxide](http://en.wikipedia.org/wiki/Carbon_dioxide), and also indirectly through the use of energy if its production involves the emission of CO2. The cement industry produces about 5% of global man-made CO2 emissions, of which 50% is from the chemical process, and 40% from burning fuel. The amount of CO2emitted by the cement industry is nearly 900 kg of CO2 for every 1000 kg of cement produced.  The high proportion of carbon dioxide produced in the chemical reaction leads to large decrease in mass in the conversion from limestone to cement. So, to reduce the transport of heavier raw materials and to mimimize the associated costs, it is more economical for cement plants to be closer to the limestone quarries rather than to the consumer centers.

In certain applications, [lime mortar](http://en.wikipedia.org/wiki/Lime_mortar) reabsorbs the same amount of CO2 as was released in its manufacture, and has a lower energy requirement in production than mainstream cement. Newly developed cement types from Novacem and [Eco-cement](http://en.wikipedia.org/wiki/Eco-cement) can absorb[carbon dioxide](http://en.wikipedia.org/wiki/Carbon_dioxide) from ambient air during hardening. Use of the [Kalina cycle](http://en.wikipedia.org/wiki/Kalina_cycle) during production can also increase energy efficiency.

### Heavy metal emissions in the air

In some circumstances, mainly depending on the origin and the composition of the raw materials used, the high-temperature calcination process of limestone and clay minerals can release in the atmosphere gases and dust rich in volatile [heavy metals](http://en.wikipedia.org/wiki/Heavy_metal_(chemistry)), a.o, [thallium](http://en.wikipedia.org/wiki/Thallium#Thallium_pollution), [cadmium](http://en.wikipedia.org/wiki/Cadmium) and [mercury](http://en.wikipedia.org/wiki/Mercury_(element)) are the most toxic. Heavy metals (Tl, Cd, Hg, ...) are often found as trace elements in common metal [sulfides](http://en.wikipedia.org/wiki/Sulfide)([pyrite (FeS2)](http://en.wikipedia.org/wiki/Pyrite), [zinc blende (ZnS)](http://en.wikipedia.org/wiki/Sphalerite), [galena (PbS)](http://en.wikipedia.org/wiki/Galena), ...) present as secondary minerals in most of the raw materials. Environmental regulations exist in many countries to limit these emissions. As of 2011 in the United States, cement kilns are "legally allowed to pump more toxins into the air than are hazardous-waste incinerators."

### Heavy metals present in the clinker

The presence of heavy metals in the clinker arises both from the natural raw materials and from the use of recycled by-products or alternative fuels. The high pH prevailing in the cement porewater (12.5 < pH < 13.5) limits the mobility of many heavy metals by decreasing their solubility and increasing their sorption onto the cement mineral phases. [Nickel](http://en.wikipedia.org/wiki/Nickel), [zinc](http://en.wikipedia.org/wiki/Zinc) and [lead](http://en.wikipedia.org/wiki/Lead) are commonly found in cement in non-negligible concentrations.

### Use of alternative fuels and by-products materials

A cement plant consumes 3 to 6 [GJ](http://en.wikipedia.org/wiki/GJ) of fuel per tonne of clinker produced, depending on the raw materials and the process used. Most cement kilns today use coal and petroleum coke as primary fuels, and to a lesser extent natural gas and fuel oil. Selected waste and by-products with recoverable calorific value can be used as fuels in a cement kiln, replacing a portion of conventional fossil fuels, like coal, if they meet strict specifications. Selected waste and by-products containing useful minerals such as calcium, silica, alumina, and iron can be used as raw materials in the kiln, replacing raw materials such as clay, [shale](http://en.wikipedia.org/wiki/Shale), and limestone. Because some materials have both useful mineral content and recoverable calorific value, the distinction between alternative fuels and raw materials is not always clear. For example, sewage sludge has a low but significant calorific value, and burns to give ash containing minerals useful in the clinker matrix.

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