

Types of concrete

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There are many **types of concrete**, designed to suit a variety of purposes coupled with a range of compositions, finishes and performance characteristics.

Contents

- 1 Mix design
- 2 Old concrete recipes
- 3 Modern concrete
- 4 High-strength concrete
- 5 Stamped concrete
- 6 High-performance concrete
 - 6.1 Ultra-high-performance concrete
 - 6.2 Micro-reinforced ultra-high-performance concrete
- 7 Self-consolidating concrete
- 8 Vacuum concrete
- 9 Shotcrete
- 10 Limecrete
- 11 Pervious concrete
 - 11.1 Installation
 - 11.2 Characteristics
- 12 Cellular concrete
- 13 Cork-cement composites
- 14 Roller-compacted concrete
- 15 Glass concrete
- 16 Asphalt concrete
- 17 Rapid strength concrete
- 18 Rubberized concrete
- 19 Polymer concrete
- 20 Geopolymer concrete
- 21 Refractory cement
- 22 Innovative mixtures
- 23 Gypsum concrete
- 24 See also
- 25 References



A highway paved with concrete.



Regular concrete paving blocks



Concrete in sidewalk stamped with contractor name and date it was laid

Mix design

Modern **concrete mix** designs can be complex. The choice of a concrete mix depends on the need of the project both in terms of strength and appearance and in relation to local legislation and building codes.

The design begins by determining the requirements of the concrete. These requirements take into consideration the weather conditions that the concrete will be exposed to in service, and the required design strength. The compressive strength of a concrete is determined by taking standard molded, standard-cured cylinder samples.

Many factors need to be taken into account, from the cost of the various additives and aggregates, to the trade offs between the "slump" for easy mixing and placement and ultimate performance.

A mix is then designed using cement (Portland or other cementitious material), coarse and fine aggregates, water and chemical admixtures. The method of mixing will also be specified, as well as conditions that it may be used in.

This allows a user of the concrete to be confident that the structure will perform properly.

Various types of concrete have been developed for specialist application and have become known by these names.

Concrete mixes can also be designed using software programs. Such software provides the user an opportunity to select their preferred method of mix design and enter the material data to arrive at proper mix designs.

Old concrete recipes

Concrete has been used since ancient times. Regular Roman concrete for example was made from volcanic ash (pozzolana), and hydrated lime. Roman concrete was superior to other concrete recipes (for example, those consisting of only sand and lime)^[1] used by other nations. Besides volcanic ash for making regular Roman concrete, brick dust can also be utilized. Besides regular Roman concrete, the Romans also invented hydraulic concrete, which they made from volcanic ash and clay.

Modern concrete

Regular concrete is the lay term for concrete that is produced by following the mixing instructions that are commonly published on packets of cement, typically using sand or other common material as the aggregate, and often mixed in improvised containers. The ingredients in any particular mix depends on the nature of the application. Regular concrete can typically withstand a pressure from about 10 MPa (1450 psi) to 40 MPa (5800 psi), with lighter duty uses such as blinding concrete having a much lower MPa rating than structural concrete. Many types of pre-mixed concrete are available which include powdered cement mixed with an aggregate, needing only water.

Typically, a batch of concrete can be made by using 1 part Portland cement, 2 parts dry sand, 3 parts dry stone, 1/2 part water. The parts are in terms of weight – not volume. For example, 1-cubic-foot (0.028 m³) of concrete would be made using 22 lb (10.0 kg) cement, 10 lb (4.5 kg) water, 41 lb (19 kg) dry sand, 70 lb (32 kg) dry stone (1/2" to 3/4" stone). This would make 1-cubic-foot (0.028 m³) of concrete and would weigh about 143 lb (65 kg). The sand should be mortar or brick sand (washed and filtered if possible) and the stone should be washed if possible. Organic materials (leaves, twigs, etc.) should be removed from the sand and stone to ensure the highest strength.

High-strength concrete

High-strength concrete has a compressive strength greater than 40 MPa (5800 psi). In the UK, BS EN 206-1^[2] defines High strength concrete as concrete with a compressive strength class higher than C50/60. High-strength concrete is made by lowering the water-cement (W/C) ratio to 0.35 or lower. Often silica fume is added to prevent the formation of free calcium hydroxide crystals in the cement matrix, which might reduce the strength at the cement-aggregate bond.

Low W/C ratios and the use of silica fume make concrete mixes significantly less workable, which is particularly likely to be a problem in high-strength concrete applications where dense rebar cages are likely to be used. To compensate for the reduced workability, superplasticizers are commonly added to high-strength mixtures. Aggregate must be selected carefully for high-strength mixes, as weaker aggregates may not be strong enough to resist the loads imposed on the concrete and cause failure to start in the aggregate rather than in the matrix or at a void, as normally occurs in regular concrete.

In some applications of high-strength concrete the design criterion is the elastic modulus rather than the ultimate compressive strength.

Stamped concrete

Stamped concrete is an architectural concrete which has a superior surface finish. After a concrete floor has been laid, floor hardeners (can be pigmented) are impregnated on the surface and a mold which may be textured to replicate a stone / brick or even wood is stamped on to give an attractive textured surface finish. After sufficient hardening the surface is cleaned and generally sealed to give a protection. The wear resistance of stamped concrete is generally excellent and hence found in applications like parking lots, pavements, walkways etc.

High-performance concrete

High-performance concrete (HPC) is a relatively new term for concrete that conforms to a set of standards above those of the most common applications, but not limited to strength. While all high-strength concrete is also high-performance, not all high-performance concrete is high-strength. Some examples of such standards currently used in relation to HPC are:

- Ease of placement
- Compaction without segregation
- Early age strength
- Long-term mechanical properties
- Permeability
- Density
- Heat of hydration
- Toughness
- Volume stability
- Long life in severe environments
- Depending on its implementation, environmental^[3]

Ultra-high-performance concrete

Ultra-high-performance concrete is a new type of concrete that is being developed by agencies concerned with infrastructure protection. UHPC is characterized by being a steel fibre-reinforced cement composite material with compressive strengths in excess of 150 MPa, up to and possibly exceeding 250 MPa.^{[4][5][6]} UHPC is also characterized by its constituent material make-up: typically fine-grained sand, silica fume, small steel fibers, and special blends of high-strength Portland cement. Note that there is no large aggregate. The current types in production (Ductal, Taktl, etc.) differ from normal concrete in compression by their strain hardening, followed by sudden brittle failure. Ongoing research into UHPC failure via tensile and shear failure is being conducted by multiple government agencies and universities around the world.

Micro-reinforced ultra-high-performance concrete

Micro-reinforced ultra-high-performance concrete is the next generation of UHPC. In addition to high compressive strength, durability and abrasion resistance of UHPC, micro-reinforced UHPC is characterized by extreme ductility, energy absorption and resistance to chemicals, water and temperature.^[7] The continuous, multi-layered, three dimensional micro-steel mesh exceeds UHPC in durability, ductility and strength. The performance of the discontinuous and scattered fibers in UHPC is relatively unpredictable. Micro-reinforced UHPC is used in blast, ballistic and earthquake resistant construction, structural and architectural overlays, and complex facades.

Ducon was the early developer of micro-reinforced UHPC,^{[8][9]} which has been used in the construction of new World Trade Center in New York.^{[10][11][12]}

Self-consolidating concrete

The defects in concrete in Japan were found to be mainly due to high water-cement ratio to increase workability. Poor compaction occurred mostly because of the need for speedy construction in the 1960s and 1970s. Hajime Okamura envisioned the need for concrete which is highly workable and does not rely on the mechanical force for compaction. During the 1980s, Okamura and his Ph.D. student Kazamasa Ozawa at the University of Tokyo developed self-compacting concrete (SCC) which was cohesive, but flowable and took the shape of the formwork without use of any mechanical compaction. SCC is known as self-consolidating concrete in the United States.

SCC is characterized by the following:

- extreme fluidity as measured by *flow*, typically between 650–750 mm on a flow table, rather than slump (height)
- no need for vibrators to compact the concrete
- easier placement
- no bleeding, or aggregate segregation
- increased liquid head pressure, which can be detrimental to safety and workmanship

SCC can save up to 50% in labor costs due to 80% faster pouring and reduced wear and tear on formwork.

In 2005, self-consolidating concretes accounted for 10–15% of concrete sales in some European countries. In the precast concrete industry in the U.S., SCC represents over 75% of concrete production. 38 departments of transportation in the US accept the use of SCC for road and bridge projects.

This emerging technology is made possible by the use of polycarboxylates plasticizer instead of older naphthalene-based polymers, and viscosity modifiers to address aggregate segregation.

Vacuum concrete

Vacuum concrete, made by using steam to produce a vacuum inside a concrete mixing truck to release air bubbles inside the concrete, is being researched. The idea is that the steam displaces the air normally over the concrete. When the steam condenses into water it will create a low pressure over the concrete that will pull air from the concrete. This will make the concrete stronger due to there being less air in the mixture. A drawback is that the mixing has to be done in an airtight container.

The final strength of concrete is increased by about 25%. Sufficient decrease in The permeability of concrete is sufficiently decreased. Vacuum concrete stiffens very rapidly so that the formworks can be removed within 30 minutes of casting even on columns of 20 ft. high. This is of considerable economic value, particularly in a precast factory as the forms can be reused at frequent intervals. The bond strength of vacuum concrete is about 20% higher. The density of vacuum concrete is higher. The surface of vacuum concrete is entirely free from pitting and the uppermost 1/16 inch is highly resistant to abrasion. These characteristics are of special importance in the construction of concrete structures which are to be in contact with flowing water at a high velocity. It bonds well to old concrete and can, therefore, be used for resurfacing road slabs and other repair work - See more at: <http://civiltoday.com/civil-engineering-materials/concrete/27-vacuum-concrete-definition-advantages#sthash.c17jlbZ8.dpuf>

Shotcrete

Shotcrete (also known by the trade name *Gunitite*) uses compressed air to shoot concrete onto (or into) a frame or structure. The greatest advantage of the process is that shotcrete can be applied overhead or on vertical surfaces without formwork. It is often used for concrete repairs or placement on bridges, dams, pools, and on other applications where forming is costly or material handling and installation is difficult. Shotcrete is frequently used against vertical soil or rock surfaces, as it eliminates the need for formwork. It is sometimes used for rock support, especially in tunneling. Shotcrete is also used for applications where seepage is an issue to limit the amount of water entering a construction site due to a high water table or other subterranean sources. This type of concrete is often used as a quick fix for weathering for loose soil types in construction zones.

There are two application methods for shotcrete.

- *dry-mix* – the dry mixture of cement and aggregates is filled into the machine and conveyed with compressed air through the hoses. The water needed for the hydration is added at the nozzle.
- *wet-mix* – the mixes are prepared with all necessary water for hydration. The mixes are pumped through the hoses. At the nozzle compressed air is added for spraying.

For both methods additives such as accelerators and fiber reinforcement may be used.^[13]

Limecrete

Limecrete or lime concrete is concrete where cement is replaced by lime.^[14] One successful formula was developed in the mid-1800s by Dr. John E. Park.^[15] We know that lime has been used since Roman Times either as mass foundation concretes or as lightweight concretes using a variety of aggregates combined with a wide range of pozzolans (fired materials) that help to achieve increased strength and speed of set. This meant that lime could be used in a much wider variety of applications than previously such as floors, vaults or domes. Over the last decade, there has been a renewed interest in using lime for these applications again. This is because of environmental benefits and potential health benefits, when used with other lime products.

Environmental Benefits

- Lime is burnt at a lower temperature than cement and so has an immediate energy saving of 20% (although kilns etc. are improving so figures do change). A standard lime mortar has about 60-70% of the embodied energy of a cement mortar. It is also considered to be more environmentally friendly because of its ability, through carbonation, to re-absorb its own weight in Carbon Dioxide (compensating for that given off during burning).

- Lime mortars allow other building components such as stone, wood and bricks to be reused and recycled because they can be easily cleaned of mortar/limewash.
- Lime enables other natural and sustainable products such as wood (including woodfibre, wood wool boards), hemp, straw etc. to be used because of its ability to control moisture (if cement were used, these buildings would compost!).

Health Benefits

- Lime plaster is hygroscopic (literally means 'water seeking') which draws the moisture from the internal to the external environment, this helps to regulate humidity creating a more comfortable living environment as well as helping to control condensation and mould growth which have been shown to have links to allergies and asthmas.
- Lime plasters and limewash are non-toxic, therefore they do not contribute to indoor air pollution unlike some modern paints.

Pervious concrete

Pervious concrete, used in permeable paving, contains a network of holes or voids, to allow air or water to move through the concrete

This allows water to drain naturally through it, and can both remove the normal surface-water drainage infrastructure, and allow replenishment of groundwater when conventional concrete does not.

It is formed by leaving out some or all of the fine aggregate (fines). The remaining large aggregate then is bound by a relatively small amount of Portland cement. When set, typically between 15% and 25% of the concrete volume is voids, allowing water to drain at around 5 gal/ft²/ min (70 L/m²/min) through the concrete.

Installation

Pervious concrete is installed by being poured into forms, then screeded off, to level (not smooth) the surface, then packed or tamped into place. Due to the low water content and air permeability, within 5–15 minutes of tamping, the concrete must be covered with a 6-mil poly plastic, or it will dry out prematurely and not properly hydrate and cure.

Characteristics

Pervious concrete can significantly reduce noise, by allowing air to be squeezed between vehicle tires and the roadway to escape. This product cannot be used on major U.S. state highways currently due to the high psi ratings required by most states. Pervious concrete has been tested up to 4500 psi so far.

Cellular concrete

Aerated concrete produced by the addition of an air-entraining agent to the concrete (or a lightweight aggregate such as expanded clay aggregate or cork granules and vermiculite) is sometimes called *cellular concrete*, *lightweight aerated concrete*, *variable density concrete*, *Foam Concrete* and *lightweight or ultra-lightweight concrete*,^{[16][17]} not to be confused with aerated autoclaved concrete, which is manufactured off-site using an entirely different method.

In the 1977 work on *A Pattern Language: Towns, Buildings and Construction*, architect Christopher Alexander wrote in pattern 209 on *Good Materials*:

Regular concrete is too dense. It is heavy and hard to work. After it sets one cannot cut into it, or nail into it. And it's [*sic*] surface is ugly, cold, and hard in feeling unless covered by expensive finishes not integral to the structure.

And yet concrete, in some form, is a fascinating material. It is fluid, strong, and relatively cheap. It is available in almost every part of the world. A University of California professor of engineering sciences, P. Kumar Mehta, has even just recently found a way of converting abandoned rice husks into Portland cement.

Is there any way of combining all these good qualities of concrete and also having a material which is light in weight, easy to work, with a pleasant finish? There is. It is possible to use a whole range of ultra-lightweight concretes which have a density and compressive strength very similar to that of wood. They are easy to work with, can be nailed with ordinary nails, cut with a saw, drilled with wood-working tools, easily repaired.

We believe that ultra-lightweight concrete is one of the most fundamental bulk materials of the future.

The variable density is normally described in kg per m³, where regular concrete is 2400 kg/m³. Variable density can be as low as 300 kg/m³,^[16] although at this density it would have no structural integrity at all and would function as a filler or insulation use only. The variable density reduces strength^[16] to increase thermal^[16] and acoustical insulation by replacing the dense heavy concrete with air or a light material such as clay, cork granules and vermiculite. There are many competing products that use a foaming agent that resembles shaving cream to mix air bubbles in with the concrete. All accomplish the same outcome: to displace concrete with air.

Properties of Foamed Concrete^[18]

Dry Density (kg/m ³)	7-day Compressive Strength (N/mm ²)	Thermal Conductivity* (W/mK)	Modulus of Elasticity (kN/mm ²)	Drying Shrinkage (%)
400	0.5 – 1.0	0.10	0.8 – 1.0	0.30 – 0.35
600	1.0 – 1.5	0.11	1.0 – 1.5	0.22 – 0.25
800	1.5 – 2.0	0.17 – 0.23	2.0 – 2.5	0.20 – 0.22
1000	2.5 – 3.0	0.23 – 0.30	2.5 – 3.0	0.18 – 0.15
1200	4.5 – 5.5	0.38 – 0.42	3.5 – 4.0	0.11 – 0.19
1400	6.0 – 8.0	0.50 – 0.55	5.0 – 6.0	0.09 – 0.07
1600	7.5 – 10.0	0.62 – 0.66	10.0 – 12.0	0.07 – 0.06

Applications of foamed concrete include:

- Roof Insulation
- Blocks and Panels for Walls
- Levelling Floors
- Void Filling
- Road Sub-Bases and maintenance
- Bridge Abutments and repairs
- Ground Stabilisation

Cork-cement composites

Waste Cork granules are obtained during production of bottle stoppers from the treated bark of Cork oak.^[19] These granules have a density of about 300 kg/m³, lower than most lightweight aggregates used for making lightweight concrete. Cork granules do not significantly influence cement hydration, but cork dust may.^[20] Cork

cement composites have several advantages over standard concrete, such as lower thermal conductivities, lower densities and good energy absorption characteristics. These composites can be made of density from 400 to 1500 kg/m³, compressive strength from 1 to 26 MPa, and flexural strength from 0.5 to 4.0 MPa.

Roller-compacted concrete

Roller-compacted concrete, sometimes called **rollcrete**, is a low-cement-content stiff concrete placed using techniques borrowed from earthmoving and paving work. The concrete is placed on the surface to be covered, and is compacted in place using large heavy rollers typically used in earthwork. The concrete mix achieves a high density and cures over time into a strong monolithic block.^[21] Roller-compacted concrete is typically used for concrete pavement, but has also been used to build concrete dams, as the low cement content causes less heat to be generated while curing than typical for conventionally placed massive concrete pours.

Glass concrete

The use of recycled glass as aggregate in concrete has become popular in modern times, with large scale research being carried out at Columbia University in New York. This greatly enhances the aesthetic appeal of the concrete. Recent research findings have shown that concrete made with recycled glass aggregates have shown better long-term strength and better thermal insulation due to its better thermal properties of the glass aggregates.^[22]

Asphalt concrete

Strictly speaking, *asphalt* is a form of concrete as well, with *bituminous* materials replacing cement as the binder.

Rapid strength concrete

This type of concrete is able to develop high resistance within few hours after being manufactured. This feature has advantages such as removing the formwork early and to move forward in the building process at record time, repair road surfaces that become fully operational in just a few hours.

Rubberized concrete

While "rubberized asphalt concrete" is common, rubberized Portland cement concrete ("rubberized PCC") is still undergoing experimental tests, as of 2009.^[23] ^[24] ^[25]^[26]

Polymer concrete

Polymer concrete is concrete which uses polymers to bind the aggregate. Polymer concrete can gain a lot of strength in a short amount of time. For example, a polymer mix may reach 5000 psi in only four hours. Polymer concrete is generally more expensive than conventional concretes.

Geopolymer concrete

Geopolymer cement is an alternative to ordinary Portland cement and is used to produce Geopolymer concrete by adding regular aggregates to a geopolymer cement slurry. It is made from inorganic aluminosilicate (Al-Si) polymer compounds that can utilise 100% recycled industrial waste (e.g. fly ash, copper slag) as the manufacturing inputs resulting in up to 80% lower carbon dioxide emissions. Greater chemical and thermal resistance, and better mechanical properties, are said to be achieved for geopolymer concrete at both atmospheric and extreme conditions.

Similar concretes have not only been used in Ancient Rome (see Roman cement), but also in the former Soviet Union in the 1950s and 1960s. Buildings in Ukraine are still standing after 45 years.

Refractory cement

High-temperature applications, such as masonry ovens and the like, generally require the use of a refractory cement; concretes based on Portland cement can be damaged or destroyed by elevated temperatures, but refractory concretes are better able to withstand such conditions. Materials may include calcium aluminate cements, fire clay, ganister and minerals high in aluminum.

Innovative mixtures

On-going research into alternative mixtures and constituents has identified potential mixtures that promise radically different properties and characteristics.

One university has identified a mixture with much smaller crack propagation that does not suffer the usual cracking and subsequent loss of strength at high levels of tensile stress. Researchers have been able to take mixtures beyond 3 percent strain, past the more typical 0.1% point at which failure occurs.^[27]

Other institutions have identified magnesium silicate (talc) as an alternative ingredient to replace Portland cement in the mix. This avoids the usual high-temperature production process that is very energy and greenhouse gas intensive and actually absorbs carbon dioxide while it cures.^{[28][29]}

Gypsum concrete

Gypsum concrete is a building material used as a floor underlayment^[30] used in wood-frame and concrete construction for fire ratings,^[30] sound reduction,^[30] radiant heating,^[31] and floor leveling. It is a mixture of gypsum, Portland cement, and sand.^[30]

See also

- Engineered cementitious composite
- Ferrocement
- Ready-mix concrete
- Reinforced concrete
- hand-mix concrete

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