concrete

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Introduction

Concrete is a composite material composed mainly of water, aggregate, and cement. Usually there are additives and reinforcements included to achieve the desired physical properties of the finished material. When these ingredients are mixed together, they form a fluid mass that is easily molded into shape. Over time, the cement forms a hard matrix which binds the rest of the ingredients together into a durable stone-like material with many uses.

Famous concrete structures include the Hoover Dam, the Panama Canal and the Roman Pantheon. The earliest large-scale users of concrete technology were the ancient Romans, and concrete was widely used in the Roman Empire. The Colosseum in Rome was built largely of concrete, and the concrete dome of the Pantheon is the world's largest unreinforced concrete dome.

After the Roman Empire collapsed, use of concrete became rare until the technology was re-pioneered in the mid-١٨th century. Today, concrete is the most widely used man-made material (measured by tonnage)

History

The word concrete comes from the Latin word "concretus" (meaning compact or condensed), the perfect passive participle of "concrescere", from "con-" (together) and "crescere" (to grow).

Perhaps the earliest known occurrence of cement was twelve million years ago. A deposit of cement was formed after an occurrence of oil shale located adjacent to a bed of limestone burned due to natural causes. These ancient deposits were investigated in the ١٩٦٠s and ١٩٧٠s.

On a human time-scale, small usages of concrete go back for thousands of years. The ancient Nabatea culture was using materials roughly analogous to concrete at least eight thousand years ago, some structures of which survive to this day.

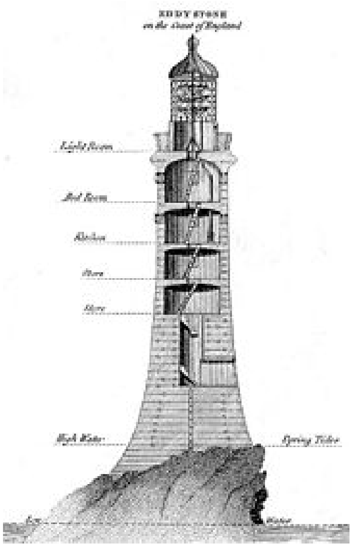
German archaeologist Heinrich Schliemann found concrete floors, which were made of lime and pebbles, in the royal palace of Tiryns, Greece, which dates roughly to ١٤٠٠-١٢٠٠ BC. Lime mortars were used in Greece, Crete, and Cyprus in ٨٠٠ BC. The Assyrian Jerwan Aqueduct (٦٨٨ BC) made use of fully waterproof concrete. Concrete was used for construction in many ancient structures.

The Romans used concrete extensively from ٣٠٠ BC to ٤٧٦ AD, a span of more than seven hundred years. During the Roman Empire, Roman concrete (or opus caementicium) was made from quicklime, pozzolana and an aggregate of pumice. Its widespread use in many Roman structures, a key event in the history of architecture termed the Roman Architectural Revolution, freed Roman construction from the restrictions of stone and brick material and allowed for revolutionary new designs in terms of both structural complexity and dimension.

Concrete, as the Romans knew it, was a new and revolutionary material. Laid in the shape of arches, vaults and domes, it quickly hardened into a rigid mass, free from many of the internal thrusts and strains that troubled the builders of similar structures in stone or brick.

Modern tests show that opus caementicium had as much compressive strength as modern Portland-cement concrete (ca. ٢٠٠ kg/cm٢). However, due to the absence of reinforcement, its tensile strength was far lower than modern reinforced concrete, and its mode of application was also different:

Modern structural concrete differs from Roman concrete in two important details. First, its mix consistency is fluid and homogeneous, allowing it to be poured into forms rather than requiring hand-layering together with the placement of aggregate, which, in Roman practice, often consisted of rubble. Second, integral reinforcing steel gives modern concrete assemblies great strength in tension, whereas Roman concrete could depend only upon the strength of the concrete bonding to resist tension.



Eddystone Lighthouse.

The widespread use of concrete in many Roman structures ensured that many survive to the present day. The Baths of Caracalla in Rome are just one example. Many Roman aqueducts and bridges such as the magnificent Pont du Gard have masonry cladding on a concrete core, as does the dome of the Pantheon.

After the Roman Empire, the use of burned lime and pozzolana was greatly reduced until the technique was all but forgotten between ٥٠٠ AD and the ١٣٠٠s. Between the ١٣٠٠s until the mid-١٧٠٠s, the use of cement gradually returned. The Canal du Midi was built using concrete in ١٦٧٠, and there are concrete structures in Finland that date from the ١٦th century.[citation needed]

Perhaps the greatest driver behind the modern usage of concrete was the third Eddystone Lighthouse in Devon, England. To create this structure, between ١٧٥٦ and ١٧٩٣, British engineer John Smeaton pioneered the use of hydraulic lime in concrete, using pebbles and powdered brick as aggregate.

A method for producing Portland cement was patented by Joseph Aspdin on ١٨٢٤.

Reinforced concrete was invented in ١٨٤٩ by Joseph Monier. In ١٨٨٩ the first concrete reinforced bridge was built, and the first large concrete dams were built in ١٩٣٦, Hoover Dam and Grand Coulee Dam.

Ancient additives

Concrete additives have been used since ٦٥٠٠BC by the Nabataea traders or Bedouins who occupied and controlled a series of oases and developed a small empire in the regions of southern Syria and northern Jordan. They later discovered the advantages of hydraulic lime—that is, cement that hardens underwater—and by ٧٠٠ BC, they were building kilns to supply mortar for the construction of rubble-wall houses, concrete floors, and underground waterproof cisterns. The cisterns were kept secret and were one of the reasons the Nabataea were able to thrive in the desert. In both Roman and Egyptian times it was re-discovered that adding volcanic ash to the mix allowed it to set underwater. Similarly, the Romans knew that adding horse hair made concrete less liable to crack while it hardened, and adding blood made it more frost-resistant.

Modern additives

In modern times, researchers have experimented with the addition of other materials to create concrete with improved properties, such as higher strength, electrical conductivity, or resistance to damages through spillage.

Impact of modern concrete use

Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, highways, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Concrete is used in large quantities almost everywhere mankind has a need for infrastructure.

The amount of concrete used worldwide, ton for ton, is twice that of steel, wood, plastics, and aluminum combined. Concrete's use in the modern world is exceeded only by that of naturally occurring water.

Concrete is also the basis of a large commercial industry. Globally, the ready-mix concrete industry, the largest segment of the concrete market, is projected to exceed $١٠٠ billion in revenue by ٢٠١٥. In the United States alone, concrete production is a $٣٠-billion-per-year industry, considering only the value of the ready-mixed concrete sold each year.Given the size of the concrete industry, and the fundamental way concrete is used to shape the infrastructure of the modern world, it is difficult to overstate the role this material plays today.

Concrete mixing plant in Birmingham, Alabama in ١٩٣٦

Composition of concrete

There are many types of concrete available, created by varying the proportions of the main ingredients below. In this way or by substitution for the cementitious and aggregate phases, the finished product can be tailored to its application with varying strength, density, or chemical and thermal resistance properties.

"Aggregate" consists of large chunks of material in a concrete mix, generally a coarse gravel or crushed rocks such as limestone, or granite, along with finer materials such as sand.

"Cement", most commonly Portland cement is associated with the general term "concrete." A range of materials can be used as the cement in concrete. One of the most familiar of these alternative cements is asphalt. Other cementitious materials such as fly ash and slag cement, are sometimes added to Portland cement and become a part of the binder for the aggregate.

Water is then mixed with this dry composite, which produces a semi-liquid that workers can shape (typically by pouring it into a form). The concrete solidifies and hardens through a chemical process called hydration. The water reacts with the cement, which bonds the other components together, creating a robust stone-like material.

"Chemical admixtures" are added to achieve varied properties. These ingredients may speed or slow down the rate at which the concrete hardens, and impart many other useful properties including increased tensile strength and water resistance.

"Reinforcements" are often added to concrete. Concrete can be formulated with high compressive strength, but always has lower tensile strength. For this reason it is usually reinforced with materials that are strong in tension (often steel).

"Mineral admixtures" are becoming more popular in recent decades. The use of recycled materials as concrete ingredients has been gaining popularity because of increasingly stringent environmental legislation, and the discovery that such materials often have complementary and valuable properties. The most conspicuous of these are fly ash, a by-product of coal-fired power plants, and silica fume, a byproduct of industrial electric arc furnaces. The use of these materials in concrete reduces the amount of resources required, as the ash and fume act as a cement replacement. This displaces some cement production, an energetically expensive and environmentally problematic process, while reducing the amount of industrial waste that must be disposed of.

The mix design depends on the type of structure being built, how the concrete is mixed and delivered, and how it is placed to form the structure.

Cement

Portland cement is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar and plaster. English masonry worker Joseph Aspdin patented Portland cement in ١٨٢٤. It was named because of the similarity of its color to Portland limestone, quarried from the English Isle of Portland and used extensively in London architecture. It consists of a mixture of oxides of calcium, silicon and aluminium. Portland cement and similar materials are made by heating limestone (a source of calcium) with clay and grinding this product (called clinker) with a source of sulfate (most commonly gypsum).

In modern cement kilns many advanced features are used to lower the fuel consumption per ton of clinker produced. Cement kilns are extremely large, complex, and inherently dusty industrial installations, and have emissions which must be controlled. Of the various ingredients used in concrete the cement is the most energetically expensive. Even complex and efficient kilns require ٣.٣ to ٣.٦ gigajoules of energy to produce a ton of clinker and then grind it into cement. Many kilns can be fueled with difficult-to-dispose-of wastes, the most common being used tires. The extremely high temperatures and long periods of time at those temperatures allows cement kilns to efficiently and completely burn even difficult-to-use fuels.

Water

Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely.

A lower water-to-cement ratio yields a stronger, more durable concrete, whereas more water gives a freer-flowing concrete with a higher slump. Impure water used to make concrete can cause problems when setting or in causing premature failure of the structure.

Hydration involves many different reactions, often occurring at the same time. As the reactions proceed, the products of the cement hydration process gradually bond together the individual sand and gravel particles and other components of the concrete to form a solid mass.

Reaction:

Cement chemist notation: $C_{٣}S + H \rightarrow C\text{-}S\text{-}H + CH$

Standard notation: $Ca_{٣}SiO_{٥} + H_{٢}O \rightarrow (CaO)\cdot(SiO_{٢})\cdot(H_{٢}O)(gel) + Ca(OH)_{٢}$

Balanced: $٢Ca_{٣}SiO_{٥} + ٧H_{٢}O \rightarrow ٣(CaO)\cdot٢(SiO_{٢})\cdot٤(H_{٢}O)(gel) + ٣Ca(OH)_{٢}$

Aggregates

Fine and coarse aggregates make up the bulk of a concrete mixture. Sand, natural gravel, and crushed stone are used mainly for this purpose. Recycled aggregates (from construction, demolition, and excavation waste) are increasingly used as partial replacements of natural aggregates, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are also permitted.

The presence of aggregate greatly increases the durability of concrete above that of cement, which is a brittle material in its pure state. Thus concrete is a true composite material.

Redistribution of aggregates after compaction often creates inhomogeneity due to the influence of vibration. This can lead to strength gradients.

Decorative stones such as quartzite, small river stones or crushed glass are sometimes added to the surface of concrete for a decorative "exposed aggregate" finish, popular among landscape designers.

In addition to being decorative, exposed aggregate adds robustness to a concrete driveway.

Crushed stone aggregate

Reinforcement

Concrete is strong in compression, as the aggregate efficiently carries the compression load. However, it is weak in tension as the cement holding the aggregate in place can crack, allowing the structure to fail. Reinforced concrete adds either steel reinforcing bars, steel fibers, glass fibers, or plastic fibers to carry tensile loads.

Constructing a rebar cage. This cage will be

permanently embedded in poured concrete to create a reinforced concrete structure.

Chemical admixtures

Chemical admixtures are materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes. In normal use, admixture dosages are less than ٥% by mass of cement and are added to the concrete at the time of batching/mixing. (See the section on Concrete Production, below.)The common types of admixtures are as follows.

Accelerators speed up the hydration (hardening) of the concrete. Typical materials used are $CaCl_{٢}$, $Ca(NO_{٣})_{٢}$ and $NaNO_{٣}$. However, use of chlorides may cause corrosion in steel reinforcing and is prohibited in

some countries, so that nitrates may be favored.

Retarders slow the hydration of concrete and are used in large or difficult pours where partial setting before the pour is complete is undesirable. Typical polyol retarders are sugar, sucrose, sodium gluconate, glucose, citric acid, and tartaric acid.

Air entrainments add and entrain tiny air bubbles in the concrete, which reduces damage during freeze-thaw cycles, increasing durability. However, entrained air entails a trade off with strength, as each ١% of air may decrease compressive strength ٥%.

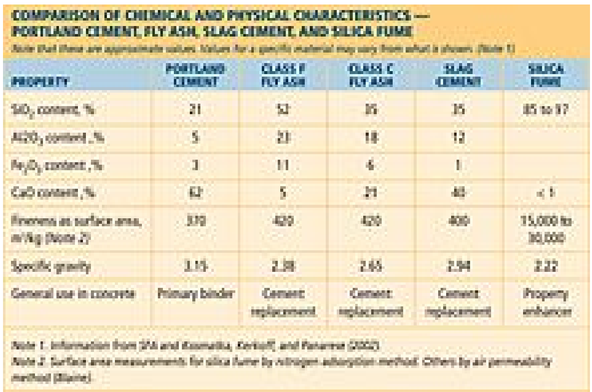
Plasticizers increase the workability of plastic or "fresh" concrete, allowing it be placed more easily, with less consolidating effort. A typical plasticizer is lignosulfonate. Plasticizers can be used to reduce the water content of a concrete while maintaining workability and are sometimes called water-reducers due to this use. Such treatment improves its strength and durability characteristics. Superplasticizers (also called high-range water-reducers) are a class of plasticizers that have fewer deleterious effects and can be used to increase workability more than is practical with traditional plasticizers. Compounds used as superplasticizers include sulfonated naphthalene formaldehyde condensate, sulfonated melamine formaldehyde condensate, acetone formaldehyde condensate and polycarboxylate ethers.

Pigments can be used to change the color of concrete, for aesthetics.

Corrosion inhibitors are used to minimize the corrosion of steel and steel bars in concrete.

Bonding agents are used to create a bond between old and new concrete (typically a type of polymer) with wide temperature tolerance and corrosion resistance.

Pumping aids improve pumpability, thicken the paste and reduce separation and bleeding.



COMPARISON OF CHEMICAL AND PHYSICAL CHARACTERISTICS — PORTLAND CEMENT, FLY ASH, SLAG CEMENT, AND SILICA FUME

Note that these are approximate values. Values for a specific material may vary from what is shown. (Note 1)

PROPERTY	PORTLAND CEMENT	CLASS F FLY ASH	CLASS C FLY ASH	SLAG CEMENT	SILICA FUME
SiO_2 content, %	21	52	35	35	85 to 97
Al_2O_3 content, %	5	23	18	12	
Fe_2O_3 content, %	3	11	6	1	
CaO content, %	62	5	21	40	< 1
Fineness as surface area, m^2/kg (Note 2)	370	420	420	400	15,000 to 30,000
Specific gravity	3.15	2.38	2.65	2.94	2.22
General use in concrete	Primary binder	Cement replacement	Cement replacement	Cement replacement	Property enhancer

Note 1. Information from SFA and Kosmatka, Kerkhoff, and Panarese (2002).
Note 2. Surface area measurements for silica fume by nitrogen adsorption method. Others by air permeability method (Blaine).

Comparison of chemical and

physical characteristics of Portland,

fly ash, slag, and silica fume cements.

Mineral admixtures and blended cements

There are inorganic materials that also have pozzolanic or latent hydraulic properties. These very fine-grained materials are added to the concrete mix to improve the properties of concrete (mineral admixtures), or as a replacement for Portland cement (blended cements). Products which incorporate limestone, fly ash, blast furnace slag, and other useful materials with pozzolanic properties into the mix, are being tested and used. This development is due to cement production being one of the largest producers (at about ٥ to ١٠%) of global greenhouse gas emissions, as well as lowering costs, improving concrete properties, and recycling wastes.

Fly ash: A by-product of coal-fired electric generating plants, it is used to partially replace Portland cement (by up to ٦٠% by mass). The properties of fly ash depend on the type of coal burnt. In general, siliceous fly ash is pozzolanic, while calcareous fly ash has latent hydraulic properties.

Ground granulated blast furnace slag (GGBFS or GGBS): A by-product of steel production is used to partially replace Portland cement (by up to ٨٠% by mass). It has latent hydraulic properties.

Silica fume: A byproduct of the production of silicon and ferrosilicon alloys. Silica fume is similar to fly ash, but has a particle size ١٠٠ times smaller. This results in a higher surface-to-volume ratio and a much faster pozzolanic reaction. Silica fume is used to increase strength and durability of concrete, but generally requires the use of superplasticizers for workability.

High reactivity Metakaolin (HRM): Metakaolin produces concrete with strength and durability similar to concrete made with silica fume. While silica fume is usually dark gray or black in color, high-reactivity metakaolin is usually bright white in color, making it the preferred choice for architectural concrete where appearance is important.

Concrete production

Concrete production is the process of mixing together the various ingredients—water, aggregate, cement, and any additives—to produce concrete. Concrete production is time-sensitive. Once the ingredients are mixed, workers must put the concrete in place before it hardens. In modern usage, most concrete production takes place in a large type of industrial facility called a concrete plant, or often a batch plant.

In general usage, concrete plants come in two main types, ready mix plants and central mix plants. A ready mix plant mixes all the ingredients except water, while a central mix plant mixes all the ingredients including water. A central mix plant offers more accurate control of the concrete quality through better measurements of the amount of water added, but must be placed closer to the work site where the concrete will be used, since hydration begins at the plant.

A concrete plant consists of large storage hoppers for various reactive ingredients like cement, storage for bulk ingredients like aggregate and water, mechanisms for the addition of various additives and amendments, machinery to accurately weigh, move, and mix some or all of those ingredients, and facilities to dispense the mixed concrete, often to a concrete mixer truck.

Modern concrete is usually prepared as a viscous fluid, so that it may be poured into forms, which are containers erected in the field to give the concrete its desired shape. There are many different ways in which concrete formwork can be prepared, such as Slip forming and Steel plate construction. Alternatively, concrete can be mixed into dryer, non-fluid forms and used in factory settings to manufacture Precast concrete products.

There is a wide variety of equipment for processing concrete, from hand tools to heavy industrial machinery. Whichever equipment builders use, however, the objective is to produce the desired building material; ingredients must be properly mixed, placed, shaped, and retained within time constraints. Once the mix is where it should be, the curing process must be controlled to ensure that the concrete attains the desired attributes. During concrete preparation, various technical details may affect the quality and nature of the product.

When initially mixed, Portland cement and water rapidly form a gel of tangled chains of interlocking crystals, and components of the gel continue to react over time. Initially the gel is fluid, which improves workability and aids in placement of the material, but as the concrete sets, the chains of crystals join into a rigid structure, counteracting the fluidity of the gel and fixing the particles of aggregate in place. During curing, the cement continues to react with the residual water in a process of hydration. In properly formulated concrete, once this curing process has terminated the product has the desired physical and chemical properties. Among the qualities typically desired, are mechanical strength, low moisture permeability, and chemical and volumetric stability.

Concrete plant facility showing a Concrete mixer being filled from the ingredient silos.

Mixing concrete

Thorough mixing is essential for the production of uniform, high-quality concrete. For this reason equipment and methods should be capable of effectively mixing concrete materials containing the largest specified aggregate to produce uniform mixtures of the lowest slump practical for the work.

Separate paste mixing has shown that the mixing of cement and water into a paste before combining these materials with aggregates can increase the compressive strength of the resulting concrete. The paste is generally mixed in a high-speed, shear-type mixer at a w/cm (water to cement ratio) of ٠.٣٠ to ٠.٤٥ by mass. The cement paste premix may include admixtures such as accelerators or retarders, superplasticizers, pigments, or silica fume. The premixed paste is then blended with aggregates and any remaining batch water and final mixing is completed in conventional concrete mixing equipment.

High-energy mixed (HEM) concrete is produced by means of high-speed mixing of cement, water and sand with net specific energy consumption of at least ٥ kilojoules per kilogram of the mix. A plasticizer or a superplasticizer is then added to the activated mixture, which can later be mixed with aggregates in a conventional concrete mixer. In this process, sand provides dissipation of energy and creates high-shear conditions on the surface of cement particles. This results in the full volume of water interacting with cement. The liquid activated mixture can be used by itself or foamed (expanded) for lightweight concrete. HEM concrete hardens in low and subzero temperature conditions and possesses an increased volume of gel, which drastically reduces capillarity in solid and porous materials.

Workability

Pouring and smoothing out concrete at Palisades Park in Washington DC.

Workability is the ability of a fresh (plastic) concrete mix to fill the form/mold properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration) and can be modified by adding chemical admixtures, like superplasticizer. Raising the water content or adding chemical admixtures increases concrete workability. Excessive water leads to increased bleeding (surface water) and/or segregation of aggregates (when the cement and aggregates start to separate), with the resulting concrete having reduced quality. The use of an aggregate with an undesirable gradation can result in a very harsh mix design with a very low slump, which cannot readily be made more workable by addition of reasonable amounts of water.

Workability can be measured by the concrete slump test, a simplistic measure of the plasticity of a fresh batch of concrete following the ASTM C ١٤٣ or EN ١٢٣٥٠-٢ test standards. Slump is normally measured by filling an "Abrams cone" with a sample from a fresh batch of concrete. The cone is placed with the wide end down onto a level, non-absorptive surface. It is then filled in three layers of equal volume, with each layer being tamped with a steel rod to consolidate the layer. When the cone is carefully lifted off, the enclosed material slumps a certain amount, owing to gravity. A relatively dry sample slumps very little, having a slump value of one or two inches (٢٥ or ٥٠ mm) out of one foot (٣٠٥ mm). A relatively wet concrete sample may slump as much as eight inches. Workability can also be measured by the flow table test.

Slump can be increased by addition of chemical admixtures such as plasticizer or superplasticizer without changing the water-cement ratio. Some other admixtures, especially air-entraining admixture, can increase the slump of a mix.

High-flow concrete, like self-consolidating concrete, is tested by other flow-measuring methods. One of these methods includes placing the cone on the narrow end and observing how the mix flows through the cone while it is gradually lifted.

After mixing, concrete is a fluid and can be pumped to the location where needed.

Curing

A concrete slab ponded while curing.

In all but the least critical applications, care must be taken to properly cure concrete, to achieve best strength and hardness. This happens after the concrete has been placed. Cement requires a moist, controlled environment to gain strength and harden fully. The cement paste hardens over time, initially setting and becoming rigid though very weak and gaining in strength in the weeks following. In around ٤ weeks, typically over ٩٠% of the final strength is reached, though strengthening may continue for decades. The conversion of calcium hydroxide in the concrete into calcium carbonate from absorption of CO٢ over several decades further strengthens the concrete and makes it more resistant to damage. However, this reaction, called carbonation, lowers the pH of the cement pore solution and can cause the reinforcement bars to corrode.

Hydration and hardening of concrete during the first three days is critical. Abnormally fast drying and shrinkage due to factors such as evaporation from wind during placement may lead to increased tensile stresses at a time when it has not yet gained sufficient strength, resulting in greater shrinkage cracking. The early strength of the concrete can be increased if it is kept damp during the curing process. Minimizing stress prior to curing minimizes cracking. High-early-strength concrete is designed to hydrate faster, often by increased use of cement that increases shrinkage and cracking. The strength of concrete changes (increases) for up to three years. It depends on cross-section dimension of elements and conditions of structure exploitation.

During this period concrete must be kept under controlled temperature and humid atmosphere. In practice, this is achieved by spraying or ponding the concrete surface with water, thereby protecting the concrete mass from ill effects of ambient conditions. The picture to the right shows one of many ways to achieve this, ponding – submerging setting concrete in water and wrapping in plastic to contain the water in the mix. Additional common curing methods include wet burlap and/or plastic sheeting covering the fresh concrete, or by spraying on a water-impermeable temporary curing membrane.

Properly curing concrete leads to increased strength and lower permeability and avoids cracking where the surface dries out prematurely. Care must also be taken to avoid freezing or overheating due to the exothermic setting of cement. Improper curing can cause scaling, reduced strength, poor abrasion resistance and cracking.

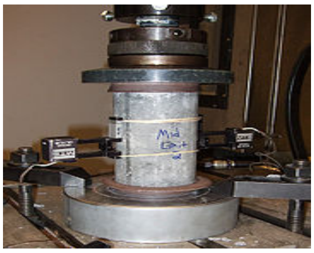
Properties

Concrete has relatively high compressive strength, but much lower tensile strength. For this reason it is usually reinforced with materials that are strong in tension (often steel). The elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as matrix cracking develops. Concrete has a very low coefficient of thermal expansion and shrinks as it matures. All concrete structures crack to some extent, due to shrinkage and tension. Concrete that is subjected to long-duration forces is prone to creep.

Tests can be performed to ensure that the properties of concrete correspond to specifications for the application.

Different mixes of concrete ingredients produce different strengths, which are measured in psi or MPa.

Different strengths of concrete are used for different purposes. Very low-strength (٢٠٠٠ psi or less) concrete may be used when the concrete must be lightweight. Lightweight concrete is often achieved by adding air, foams, or lightweight aggregates, with the side effect that the strength is reduced. For most routine uses, ٣٠٠٠-psi to ٤٠٠٠-psi concrete is often used. ٥٠٠٠-psi concrete is readily commercially available as a more durable, although more expensive, option. ٥٠٠٠-psi concrete is often used for larger civil projects. Strengths above ٥٠٠٠ psi are often used for specific building elements. For example, the lower floor columns of high-rise concrete buildings may use concrete of ١٢,٠٠٠ psi or more, to keep the size of the columns small. Bridges may use long beams of ١٠,٠٠٠ psi concrete to lower the number of spans required. Occasionally, other structural needs may require high-strength concrete. If a structure must be very rigid, concrete of very high strength may be specified, even much stronger than is required to bear the service loads. Strengths as high as ١٩,٠٠٠ psi have been used commercially for these reasons.



Compression testing of a concrete cylinder.

Imperial Strength	**Metric Equivalent**
٢,٠٠٠ psi	١٤ MPa
٢.٥٠٠ psi	١٨ MPa
٣,٠٠٠ psi	٢٠ MPa
٣,٥٠٠ psi	٢٥ MPa
٤,٠٠٠ psi	٣٠ MPa
٥,٠٠٠ psi	٣٥ MPa
٦,٠٠٠ psi	٤٠ MPa
٧,٠٠٠ psi	٥٠ MPa
٨,٠٠٠ psi	٥٥ MPa
١٠,٠٠٠ psi	٧٠ MPa
١٢,٠٠٠ psi	٨٠ MPa
١٩,٠٠٠ psi	١٣٠ MPa
٣٦,٠٠٠ psi	٢٥٠ MPa

Concrete degradation

Concrete can be damaged by many processes, such as the expansion of corrosion products of the steel reinforcement bars, freezing of trapped water, fire or radiant heat, aggregate expansion, sea water effects, bacterial corrosion, leaching, erosion by fast-flowing water, physical damage and chemical damage (from carbonatation, chlorides, sulfates and distillate water).[citation needed] The micro fungi Aspergillus Alternaria and Cladosporium were able to grow on samples of concrete used as a radioactive waste barrier in the Chernobyl reactor; leaching aluminium, iron, calcium and silicon.

Concrete spalling caused by the corrosion of rebar

Microbial concrete

Bacteria such as Bacillus pasteurii, Bacillus pseudofirmus, Bacillus cohnii, Sporosarcina pasteuri, and Arthrobacter crystallopoietes increase the compression strength of concrete through their biomass. Not all bacteria increase the strength of concrete significantly with their biomass. Bacillus sp. CT-٥. can reduce corrosion of reinforcement in reinforced concrete by up to four times. Sporosarcina pasteurii reduces water and chloride permeability. B. pasteurii increases resistance to acid. Bacillus pasteurii and B. sphaericuscan induce calcium carbonate precipitation in the surface of cracks, adding compression strength.

Environmental and health

The manufacture and use of concrete produce a wide range of environmental and social consequences. Some are harmful, some welcome, and some both, depending on circumstances. A major component of concrete is cement, which similarly exerts environmental and social effects.

The cement industry is one of the three primary producers of carbon dioxide, a major greenhouse gas. The other two are the energy production and transportation industries. As of ٢٠١١ it contributes ٧% to global anthropogenic CO٢ emissions; largely due to the sintering of limestone and clay at ١٥٠٠ C.

Concrete is used to create hard surfaces that contribute to surface runoff, which can cause heavy soil erosion, water pollution, and flooding, but conversely can be used to divert, dam, and control flooding. Concrete is a primary contributor to the urban heat island effect, though less so than asphalt.[citation needed]

Workers who cut, grind or polish concrete are at risk of inhaling airborne silica, which can lead to silicosis. Concrete dust released by building demolition and natural disasters can be a major source of dangerous air pollution.

The presence of some substances in concrete, including useful and unwanted additives, can cause health concerns due to toxicity and radioactivity. Wet concrete is highly alkaline and must be handled with proper protective equipment.

Recycled crushed concrete, to be

reused as granular fill, is loaded into

a semi-dump truck.

Concrete recycling

Concrete recycling is an increasingly common method of disposing of concrete structures. Concrete debris was once routinely shipped to landfills for disposal, but recycling is increasing due to improved environmental awareness, governmental laws and economic benefits.

Concrete, which must be free of trash, wood, paper and other such materials, is collected from demolition sites and put through a crushing machine, often along with asphalt, bricks and rocks.

Reinforced concrete contains rebar and other metallic reinforcements, which are removed with magnets and recycled elsewhere. The remaining aggregate chunks are sorted by size. Larger chunks may go through the crusher again. Smaller pieces of concrete are used as gravel for new construction projects. Aggregate base gravel is laid down as the lowest layer in a road, with fresh concrete or asphalt placed over it. Crushed recycled concrete can sometimes be used as the dry aggregate for brand new concrete if it is free of contaminants, though the use of recycled concrete limits strength and is not allowed in many jurisdictions.

On ٣ March ١٩٨٣, a government-funded research team (the VIRL research.codep) estimated that almost ١٧% of worldwide landfill was by-products of concrete based waste.

Use of concrete in infrastructure

Aerial photo of reconstruction at Taum Sauk (Missouri) pumped storage facility in late November, ٢٠٠٩. After the original reservoir failed, the new reservoir was made of roller-compacted concrete.

Mass concrete structures

Large concrete structures such as dams, navigation locks, large mat foundations, and large breakwaters generate excessive heat during cement hydration and associated expansion. To mitigate these effects post-coolingis commonly applied during construction. An early example at Hoover Dam, installed a network of pipes between vertical concrete placements to circulate cooling water during the curing process to avoid damaging overheating. Similar systems are still used; depending on volume of the pour, the concrete mix used, and ambient air temperature, the cooling process may last for many months after the concrete is placed. Various methods also are used to pre-cool the concrete mix in mass concrete structures.

Another approach to mass concrete structures that is becoming more widespread is the use of roller-compacted concrete, which uses much lower amounts of cement and water than conventional concrete mixtures and is generally not poured into place. Instead it is placed in thick layers as a semi-dry material and compacted into a dense, strong mass with rolling compactors. Because it uses less cementitious material, roller-compacted concrete has a much lower cooling requirement than conventional concrete.

Prestressed concrete structures

Prestressed concrete is a form of reinforced concrete that builds in compressive stresses during construction to oppose those experienced in use. This can greatly reduce the weight of beams or slabs, by better distributing the stresses in the structure to make optimal use of the reinforcement. For example, a horizontal beam tends to sag. Prestressed reinforcement along the bottom of the beam counteracts this. In pre-tensioned concrete, the prestressing is achieved by using steel or polymer tendons or bars that are subjected to a tensile force prior to casting, or for post-tensioned concrete, after casting.

Concrete textures

When one thinks of concrete, the image of a dull, gray concrete wall often comes to mind. With the use of form liner, concrete can be cast and molded into different textures and used for decorative concrete applications. Sound/retaining walls, bridges, office buildings and more serve as the optimal canvases for concrete art. For example, the Pima Freeway/Loop ١٠١ retaining and sound walls in Scottsdale, Arizona, feature desert flora and fauna, a ٦٧-foot (٢٠ m) lizard and ٤٠-foot (١٢ m) cacti along the ٨-mile (١٣ km) stretch. The project, titled "The Path Most Traveled," is one example of how concrete can be shaped using elastomeric form liner.

Building with concrete

The Buffalo City Court Building in Buffalo, NY.

Concrete is one of the most durable building materials. It provides superior fire resistance compared with wooden construction and gains strength over time. Structures made of concrete can have a long service life. Concrete is used more than any other manmade material in the world. As of ٢٠٠٦, about ٧.٥ billion cubic meters of concrete are made each year, more than one cubic meter for every person on Earth.

More than ٥٥,٠٠٠ miles (٨٩,٠٠٠ km) of highways in the United States are paved with this material. Reinforced concrete, prestressed concrete and precast concrete are the most widely used types of concrete functional extensions in modern days. See Brutalism.

Energy efficiency

Energy requirements for transportation of concrete are low because it is produced locally from local resources, typically manufactured within ١٠٠ kilometers of the job site. Similarly, relatively little energy is used in producing and combining the raw materials (although large amounts of CO٢ are produced by the chemical reactions in cement manufacture).[citation needed] The overall embodied energy of concrete is therefore lower than for most structural materials other than wood.[citation needed]

Once in place, concrete offers great energy efficiency over the lifetime of a building. Concrete walls leak air far less than those made of wood frames[citation needed]. Air leakage accounts for a large percentage of energy loss from a home. The thermal mass properties of concrete increase the efficiency of both residential and commercial buildings. By storing and releasing the energy needed for heating or cooling, concrete's thermal mass delivers year-round benefits by reducing temperature swings inside and minimizing heating and cooling costs. While insulation reduces energy loss through the building envelope, thermal mass uses walls to store and release energy. Modern concrete wall systems use both external insulation and thermal mass to create an energy-efficient building. Insulating concrete forms (ICFs) are hollow blocks or panels made of either insulating foam or rastra that are stacked to form the shape of the walls of a building and then filled with reinforced concrete to create the structure.

Pervious concrete

Pervious concrete is a mix of specially graded coarse aggregate, cement, water and little-to-no fine aggregates. This concrete is also known as “no-fines” or porous concrete. Mixing the ingredients in a carefully controlled process creates a paste that coats and bonds the aggregate particles. The hardened concrete contains interconnected air voids totalling approximately ١٥ to ٢٥ percent. Water runs through the voids in the pavement to the soil underneath. Air entrainment admixtures are often used in freeze–thaw climates to minimize the possibility of frost damage.

Nano concrete

Concrete is the most widely manufactured construction material. The addition of carbon nanofibres to concrete has many advantages in terms of mechanical and electrical properties (e.g. higher strength and higher Young's modulus) and self-monitoring behavior due to the high tensile strength and high conductivity. Mullapudi used the pulse velocity method to characterize the properties of concrete containing carbon nanofibres. The test results indicate that the compressive strength and percentage reduction in electrical resistance while loading concrete containing carbon nanofibres differ from those of plain concrete. A reasonable concentration of carbon nanofibres need to be determined for use in concrete, which not only enhances compressive strength, but also improves the electrical properties required for strain monitoring, damage evaluation and self-health monitoring of concrete.

Fire safety

Concrete buildings are more resistant to fire than those constructed using steel frames, since concrete has lower heat conductivity than steel and can thus last longer under the same fire conditions. Concrete is sometimes used as a fire protection for steel frames, for the same effect as above. Concrete as a fire shield, for example Fondu fyre, can also be used in extreme environments like a missile launch pad.

Options for non-combustible construction include floors, ceilings and roofs made of cast-in-place and hollow-core precast concrete. For walls, concrete masonry technology and Insulating Concrete Forms (ICFs) are additional options. ICFs are hollow blocks or panels made of fireproof insulating foam that are stacked to form the shape of the walls of a building and then filled with reinforced concrete to create the structure.

Concrete also provides good resistance against externally applied forces such as high winds, hurricanes, and tornadoes owing to its lateral stiffness, which results in minimal horizontal movement. However this stiffness can work against certain types of concrete structures, particularly where a relatively higher flexing structure is require to resist more extreme forces.

Earthquake safety

As discussed above, concrete is very strong in compression, but weak in tension. Larger earthquakes can generate very large shear loads on structures. These shear loads subject the structure to both tensile and compressional loads. Concrete structures without reinforcement, like other unreinforced masonry structures, can fail during severe earthquake shaking. Unreinforced masonry structures constitute one of the largest earthquake risks globally. These risks can be reduced through seismic retrofitting of at-risk buildings, (e.g. school buildings in Istanbul, Turkey).

Useful life

Concrete can be viewed as a form of artificial sedimentary rock. As a type of mineral, the compounds of which it is composed are extremely stable. Many concrete structures are built with an expected lifetime of approximately ١٠٠ years, but researchers have suggested that adding silica fume could extend the useful life of bridges and other concrete uses to as long as ١٦,٠٠٠ years. Coatings are also available to protect concrete from damage, and extend the useful life. Epoxy coatings may be applied only to interior surfaces, though, as they would otherwise trap moisture in the concrete.

A self-healing concrete has been developed that can also last longer than conventional concrete.

Large dams, such as the Hoover Dam, and the Three Gorges Dam are intended to last "forever", a period that is not quantified.

A modern building: Boston City Hall (completed ١٩٦٨) is constructed largely of concrete, both precast and poured in place. Of Brutalist architecture, it was voted "The World's Ugliest Building" in ٢٠٠٨.

References

١- Wikipedia,free encyclopedia website (www.wikipedia.org) .

٢- Unreinforced Masonry Buildings and Earthquakes: Developing Successful Risk Reduction Programs, FEMA P-٧٧٤ / October ٢٠٠٩

٣- CHAPTER ٩ Designing and Proportioning Normal Concrete Mixtures". PCA manual. Portland Concrete Association. Retrieved ١ October ٢٠١٢.

٤- Ready Mixed Concrete Production Statistics". NRMCA-National Ready Mixed Concrete Association. Retrieved ١٠ January ٢٠١٣.

٥- The History of Concrete and Cement. Inventors.about.com (٢٠١٢-٠٤-٠٩). Retrieved on ٢٠١٣-٠٢-١٩.

٦- Mullapudi, T.R.S., Gao, D., and Ayoub, A.S., “Nondestructive Evaluation of Carbon-Nanofiber Concrete,” Magazine of Concrete Research, ICE, V. ٦٥ (١٨), ٢٠١٣, pp. ١٠٨١-١٠٩١.