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About concrete

This article is about the construction material. For other uses, see Concrete (disambiguation).
Not to be confused with cement, grout, mortar, or plaster.

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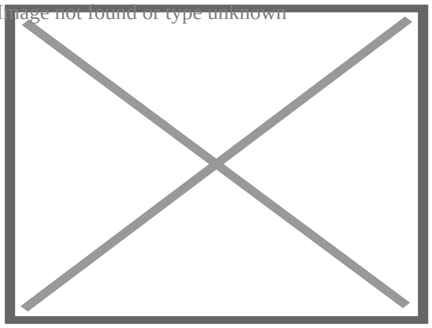


A single concrete block, as used for construction

Concrete is a composite material composed of aggregate bonded together with a fluid cement that cures to a solid over time. Concrete is the second-most-used substance in the world after water,[1] and is the most widely used building material.[2] Concrete is the most manufactured material on Earth.[3]

When aggregate is mixed with dry Portland cement and water, the mixture forms a fluid slurry that can be poured and molded into shape. The cement reacts with the water through a process called hydration[4] that hardens it over several hours to form a solid matrix that binds the materials together into a durable stone-like material that has many uses.[5] This time allows concrete to not only be cast in forms, but also to have a variety of tooled processes performed. The hydration process is exothermic, which means that ambient temperature plays a significant role in how long it takes concrete to set. Often, additives (such as pozzolans or superplasticizers) are included in the mixture to improve the physical properties of the wet mix, delay or accelerate the curing time, or otherwise modify the finished material. Most structural concrete is poured with reinforcing materials (such as steel rebar) embedded to provide tensile strength, yielding reinforced concrete.

Before the invention of Portland cement in the early 1800s, lime-based cement binders, such as lime putty, were often used. The overwhelming majority of concretes are produced using Portland cement, but sometimes with other hydraulic cements, such as calcium aluminate cement.[6][7] Many other non-cementitious types of concrete exist with other methods of binding aggregate together, including asphalt concrete with a bitumen binder, which is frequently used for road surfaces, and polymer concretes that use polymers as a binder.

Concrete is distinct from mortar.[8] Whereas concrete is itself a building material, and contains both coarse (large) and fine (small) aggregate particles, mortar contains only fine aggregates and is mainly used as a bonding agent to hold bricks, tiles and other masonry units together.[9] Grout is another material associated with concrete and cement. It also does not contain coarse aggregates and is usually either pourable or thixotropic, and is used to fill gaps between masonry components or coarse aggregate which has already been put in place. Some methods of concrete manufacture and repair involve pumping grout into the gaps to make up a solid mass *in situ*.

Etymology

[edit]

The word concrete comes from the Latin word "*concretus*" (meaning compact or condensed),[10] the perfect passive participle of "*concrescere*", from "*con*-" (together) and "*crescere*" (to grow).

History

[edit]

Ancient times

[edit]

Concrete floors were found in the royal palace of Tiryns, Greece, which dates roughly to 1400 to 1200 BC.[11][12] Lime mortars were used in Greece, such as in Crete and Cyprus, in 800 BC. The Assyrian Jerwan Aqueduct (688 BC) made use of waterproof concrete.[13] Concrete was used for construction in many ancient structures.[14]

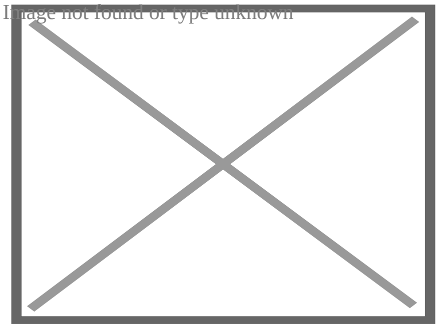
Mayan concrete at the ruins of Uxmal (AD 850–925) is referenced in *Incidents of Travel in the Yucatán* by John L. Stephens. "The roof is flat and had been covered with cement". "The floors were cement, in some places hard, but, by long exposure, broken, and now crumbling under the feet." "But throughout the wall was solid, and consisting of large stones imbedded in mortar, almost as hard as rock."

Small-scale production of concrete-like materials was pioneered by the Nabatean traders who occupied and controlled a series of oases and developed a small empire in the regions of southern Syria and northern Jordan from the 4th century BC. They discovered the advantages of hydraulic lime, with some self-cementing properties, by 700 BC. They built kilns to supply mortar for the construction of rubble masonry houses, concrete floors, and underground waterproof cisterns. They kept the cisterns secret as these enabled the Nabataeans to thrive in the desert.[15] Some of these structures survive to this day.[15]

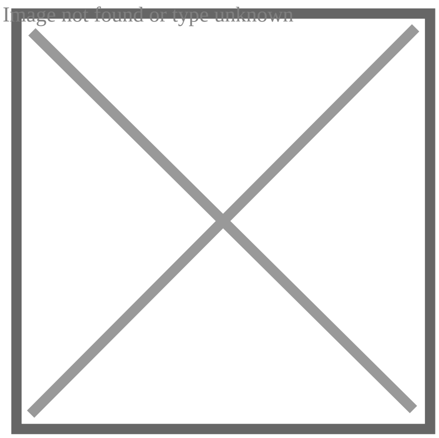
In the Ancient Egyptian and later Roman eras, builders discovered that adding volcanic ash to lime allowed the mix to set underwater. They discovered the pozzolanic reaction.[16]

Classical era

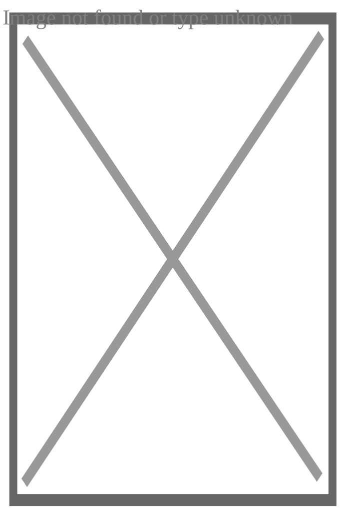
[edit]



Exterior of the Roman Pantheon, finished 128 AD, the largest unreinforced concrete dome in the world.[17]



Interior of the Pantheon dome, seen from beneath. The concrete for the coffered dome was laid on moulds, mounted on temporary scaffolding.



Opus caementicium exposed in a characteristic Roman arch. In contrast to modern concrete structures, the concrete used in Roman buildings was usually covered with brick or stone.

The Romans used concrete extensively from 300 BC to AD 476.[18] During the Roman Empire, Roman concrete (or *opus caementicium*) was made from quicklime, pozzolana and an aggregate of pumice.[19] 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 materials. It enabled revolutionary new designs in terms of both structural complexity and dimension.[20] The Colosseum in Rome was built largely of concrete, and the Pantheon has the world's largest unreinforced concrete dome.[21]

> 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.[22]

Modern tests show that *opus caementicium* had a similar compressive strength to modern Portland-cement concrete (c. 200 kg/cm^2 [20 MPa; 2,800 psi]).[23] However, due to the absence of reinforcement, its tensile strength was far lower than modern reinforced concrete, and its mode of application also differed:[24]

> 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.[25]

The long-term durability of Roman concrete structures has been found to be due to its use of pyroclastic (volcanic) rock and ash, whereby the crystallization of strätlingite (a complex calcium aluminosilicate hydrate)[26] and the coalescence of this and similar calcium–aluminium-silicate–hydrate cementing binders helped give the concrete a greater degree of fracture resistance even in seismically active environments.[27] Roman concrete is significantly more resistant to erosion by seawater than modern concrete; it used pyroclastic materials which react with seawater to form Al-tobermorite crystals over time.[28][29] The use of hot mixing and the presence of lime clasts have been proposed to give the concrete a self-healing ability, where cracks that form become filled with calcite that prevents the crack from spreading.[30][31]

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 in southern France, have masonry cladding on a concrete core, as does the dome of the Pantheon.

Middle Ages

[edit]

After the Roman Empire, the use of burned lime and pozzolana was greatly reduced. Low kiln temperatures in the burning of lime, lack of pozzolana, and poor mixing all contributed to a decline in the quality of concrete and mortar. From the 11th century, the increased use of stone in church and castle construction led to an increased demand for mortar. Quality began to improve in the 12th century through better grinding and sieving. Medieval lime mortars and concretes were non-hydraulic and were used for binding masonry, "hearting" (binding rubble masonry cores) and foundations. Bartholomaeus Anglicus in his *De proprietatibus rerum* (1240) describes the making of mortar. In an English translation from 1397, it reads "lyme ... is a stone brent; by medlynge thereof with sonde and water sement is made". From the 14th century, the quality of mortar was again excellent, but only from the 17th century was pozzolana commonly added.[32]

The *Canal du Midi* was built using concrete in 1670.[33]

Industrial era

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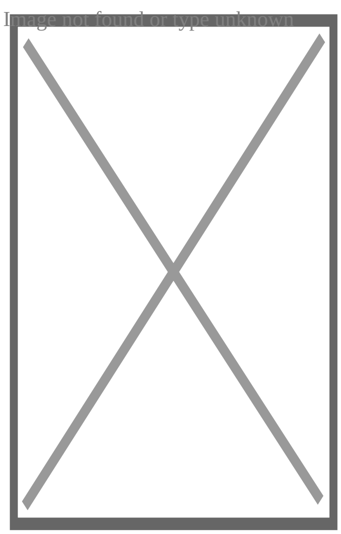


Smeaton's Tower in Devon, England

Perhaps the greatest step forward in the modern use of concrete was Smeaton's Tower, built by British engineer John Smeaton in Devon, England, between 1756 and 1759. This third Eddystone Lighthouse pioneered the use of hydraulic lime in concrete, using pebbles and powdered brick as aggregate.[34]

A method for producing Portland cement was developed in England and patented by Joseph Aspdin in 1824.[35] Aspdin chose the name for its similarity to Portland stone, which was quarried on the Isle of Portland in Dorset, England. His son William continued developments into the 1840s, earning him recognition for the development of "modern" Portland cement.[36]

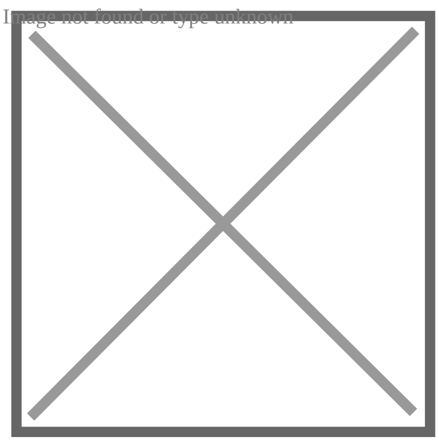
Reinforced concrete was invented in 1849 by Joseph Monier.[37] and the first reinforced concrete house was built by François Coignet[38] in 1853. The first concrete reinforced bridge was designed and built by Joseph Monier in 1875.[39]

Prestressed concrete and post-tensioned concrete were pioneered by Eugène Freyssinet, a French structural and civil engineer. Concrete components or structures are compressed by tendon cables during, or after, their fabrication in order to strengthen them against tensile forces developing when put in service. Freyssinet patented the technique on 2 October 1928.[40]

Composition

[edit]

Concrete is an artificial composite material, comprising a matrix of cementitious binder (typically Portland cement paste or asphalt) and a dispersed phase or "filler" of aggregate (typically a rocky material, loose stones, and sand). The binder "glues" the filler together to form a synthetic conglomerate.[41] Many types of concrete are available, determined by the formulations of binders and the types of aggregate used to suit the application of the engineered material. These variables determine strength and density, as well as chemical and thermal resistance of the finished product.



Cross section of a concrete railway sleeper below a rail

Construction aggregates consist 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 paste, most commonly made of Portland cement, is the most prevalent kind of concrete binder. For cementitious binders, water is mixed with the dry cement powder and aggregate, which produces a semi-liquid slurry (paste) that can be shaped, 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. Other cementitious materials, such as fly ash and slag cement, are sometimes added—either pre-blended with the cement or directly as a concrete component—and become a part of the binder for the aggregate.[42] Fly ash and slag can enhance some properties of concrete such as fresh properties and durability.[42] Alternatively, other materials can also be used as a concrete binder: the most prevalent substitute is asphalt, which is used as the binder in asphalt concrete.

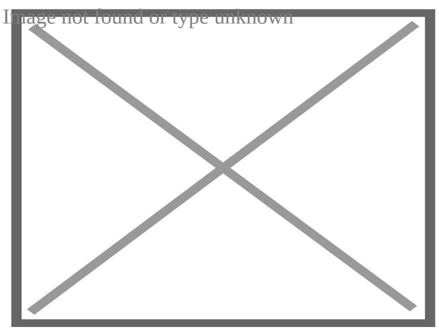
Admixtures are added to modify the cure rate or properties of the material. Mineral admixtures use recycled materials as concrete ingredients. Conspicuous materials include fly ash, a by-product of coal-fired power plants; ground granulated blast furnace slag, a by-product of steelmaking; and silica fume, a by-product of industrial electric arc furnaces.

Structures employing Portland cement concrete usually include steel reinforcement because this type of concrete can be formulated with high compressive strength, but always has lower tensile strength. Therefore, it is usually reinforced with materials that are strong in tension, typically steel rebar.

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

[edit]
Main article: Cement



Several tons of bagged cement, about two minutes of output from a 10,000 ton per day cement kiln

Portland cement is the most common type of cement in general usage. It is a basic ingredient of concrete, mortar, and many plasters.[43] It consists of a mixture of calcium silicates (alite, belite), aluminates and ferrites—compounds, which will react with water. Portland cement and similar materials are made by heating limestone (a source of calcium) with clay or shale (a source of silicon, aluminium and iron) and grinding this product (called *clinker*) with a source of sulfate (most commonly gypsum).

Cement kilns are extremely large, complex, and inherently dusty industrial installations. Of the various ingredients used to produce a given quantity of concrete, the cement is the most energetically expensive. Even complex and efficient kilns require 3.3 to 3.6 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.[44] The five major compounds of calcium silicates and aluminates comprising Portland cement range from 5 to 50% in weight.

Curing

[edit]

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.[45]

As stated by Abrams' law, a lower water-to-cement ratio yields a stronger, more durable concrete, whereas more water gives a freer-flowing concrete with a higher slump.[46] The hydration of cement involves many concurrent reactions. The process involves polymerization, the interlinking of the silicates and aluminate components as well as their bonding to sand and gravel particles to form a solid mass.[47] One illustrative conversion is the hydration of tricalcium silicate:

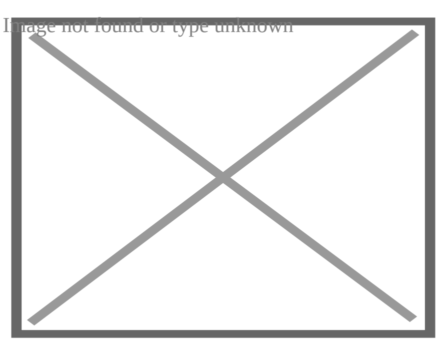
> Cement chemist notation: C_3S + H ? C-S-H + CH + heat
> Standard notation: $Ca_3SiO_5 + H_2O$? CaOÃƒÆ’Ã†â€™Ãƒâ€šÃ‚£ÃƒÆ’Ã¢â‚¬Â ÃƒÂ¢Ã¢â€šÂ¬Ã¢â€žÂ¢ÃƒÆ’Ã¢â‚¬Å¡Ãƒâ€šÃ‚»SiO_2ÃƒÆ’Ã†â€™Ãƒâ€šÃ‚£ÃƒÆ’Ã¢â‚¬Â ÃƒÂ¢Ã¢â€šÂ¬Ã¢â€žÂ¢ÃƒÆ’Ã¢â‚¬Å¡Ãƒâ€šÃ‚»H_2O (gel) + $Ca(OH)_2$ + heat
> Balanced: 2 Ca_3SiO_5 + 7 H_2O ? 3 CaOÃƒÆ’Ã†â€™Ãƒâ€šÃ‚£ÃƒÆ’Ã¢â‚¬Â ÃƒÂ¢Ã¢â€šÂ¬Ã¢â€žÂ¢ÃƒÆ’Ã¢â‚¬Å¡Ãƒâ€šÃ‚»2 SiO_2ÃƒÆ’Ã†â€™Ãƒâ€šÃ‚£ÃƒÆ’Ã¢â‚¬Â ÃƒÂ¢Ã¢â€šÂ¬Ã¢â€žÂ¢ÃƒÆ’Ã¢â‚¬Å¡Ãƒâ€šÃ‚»4 H_2O (gel) + 3 $Ca(OH)_2$ + heat
> (approximately as the exact ratios of CaO, SiO_2 and H_2O in C-S-H can vary)[47]

The hydration (curing) of cement is irreversible.[48]

Aggregates

[edit]

Main article: Construction aggregate



Crushed stone 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 for natural aggregates, while a number of manufactured aggregates, including air-cooled blast furnace slag and bottom ash are also permitted.

The size distribution of the aggregate determines how much binder is required. Aggregate with a very even size distribution has the biggest gaps whereas adding aggregate with smaller particles tends to fill these gaps. The binder must fill the gaps between the aggregate as well as paste the surfaces of the aggregate together, and is typically the most expensive component. Thus, variation in sizes of the aggregate reduces the cost of concrete.[49] The aggregate is nearly always stronger than the binder, so its use does not negatively affect the strength of the concrete.

Redistribution of aggregates after compaction often creates non-homogeneity due to the influence of vibration. This can lead to strength gradients.[50]

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.

Admixtures

[edit]

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. Admixtures are defined as additions "made as the concrete mix is being prepared".[51] The most common admixtures are retarders and accelerators. In normal use, admixture dosages are less than 5% by mass of cement and are added to the concrete at the time of batching/mixing.[52] (See § Production below.) The common types of admixtures[53] are as follows:

- Accelerators speed up the hydration (hardening) of the concrete. Typical materials used are calcium chloride, calcium nitrate and sodium nitrate. However, use of chlorides may cause corrosion in steel reinforcing and is prohibited in some countries, so that nitrates may be favored, even though they are less effective than the chloride salt. Accelerating admixtures are especially useful for modifying the properties of concrete in cold weather.
- Air entraining agents add and entrain tiny air bubbles in the concrete, which reduces damage during freeze-thaw cycles, increasing durability. However, entrained air entails a tradeoff with strength, as each 1% of air may decrease compressive strength by 5%.[54] If too much air becomes trapped in the concrete as a result of the mixing process, defoamers can be used to encourage the air bubble to agglomerate, rise to the surface of the wet concrete and then disperse.

- 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.
- Corrosion inhibitors are used to minimize the corrosion of steel and steel bars in concrete.
- Crystalline admixtures are typically added during batching of the concrete to lower permeability. The reaction takes place when exposed to water and un-hydrated cement particles to form insoluble needle-shaped crystals, which fill capillary pores and micro-cracks in the concrete to block pathways for water and waterborne contaminates. Concrete with crystalline admixture can expect to self-seal as constant exposure to water will continuously initiate crystallization to ensure permanent waterproof protection.
- Pigments can be used to change the color of concrete, for aesthetics.
- Plasticizers increase the workability of plastic, or "fresh", concrete, allowing it to 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. Superplasticizers are used to increase compressive strength. It increases the workability of the concrete and lowers the need for water content by 15–30%.
- Pumping aids improve pumpability, thicken the paste and reduce separation and bleeding.
- Retarders slow the hydration of concrete and are used in large or difficult pours where partial setting is undesirable before completion of the pour. Typical retarders include sugar, sodium gluconate, citric acid, and tartaric acid.[55]

Mineral admixtures and blended cements

[edit]

Components of cement:
comparison of chemical and physical characteristics[a][56][57][58]

Property		Portland cement	Siliceous[b] fly ash	Calcareous[c] fly ash	Slag cement	Silica fume
Proportion by mass (%)	SiO_2	21.9	52	35	35	85–97
	Al_2O_3	6.9	23	18	12	—
	Fe_2O_3	3	11	6	1	—
	CaO	63	5	21	40	< 1
	MgO	2.5	—	—	—	—
	SO_3	1.7	—	—	—	—

Specific surface (m^2/kg) [d]	370	420	420	400	15,000 – 30,000
Specific gravity	3.15	2.38	2.65	2.94	2.22
General purpose	Primary binder	Cement replacement	Cement replacement	Cement replacement	Property enhancer

1. ^ Values shown are approximate: those of a specific material may vary.
2. ^ ASTM C618 Class F
3. ^ ASTM C618 Class C
4. ^ Specific surface measurements for silica fume by nitrogen adsorption (BET) method, others by air permeability method (Blaine).

Inorganic materials that 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),[52] or as a replacement for Portland cement (blended cements).[59] Products which incorporate limestone, fly ash, blast furnace slag, and other useful materials with pozzolanic properties into the mix, are being tested and used. These developments are ever growing in relevance to minimize the impacts caused by cement use, notorious for being one of the largest producers (at about 5 to 10%) of global greenhouse gas emissions.[60] The use of alternative materials also is capable of lowering costs, improving concrete properties, and recycling wastes, the latest being relevant for circular economy aspects of the construction industry, whose demand is ever growing with greater impacts on raw material extraction, waste generation and landfill practices.

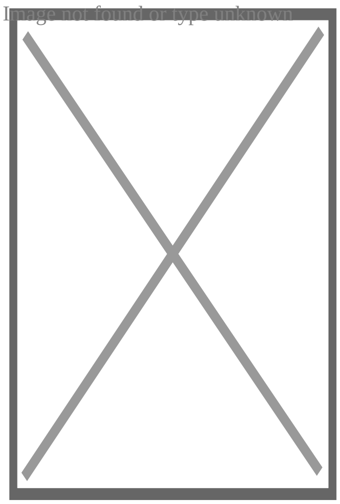
- Fly ash: A by-product of coal-fired electric generating plants, it is used to partially replace Portland cement (by up to 60% by mass). The properties of fly ash depend on the type of coal burnt. In general, siliceous fly ash is pozzolanic, while calcareous fly ash has latent hydraulic properties.[61]
- Ground granulated blast furnace slag (GGBFS or GGBS): A by-product of steel production is used to partially replace Portland cement (by up to 80% by mass). It has latent hydraulic properties.[62]
- Silica fume: A by-product of the production of silicon and ferrosilicon alloys. Silica fume is similar to fly ash, but has a particle size 100 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.[63]
- 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.
- Carbon nanofibers can be added to concrete to enhance compressive strength and gain a higher Young's modulus, and also to improve the electrical properties required for strain monitoring, damage evaluation and self-health monitoring of concrete. Carbon fiber has many advantages in terms of mechanical and electrical properties (e.g., higher strength) and self-

monitoring behavior due to the high tensile strength and high electrical conductivity.[64]

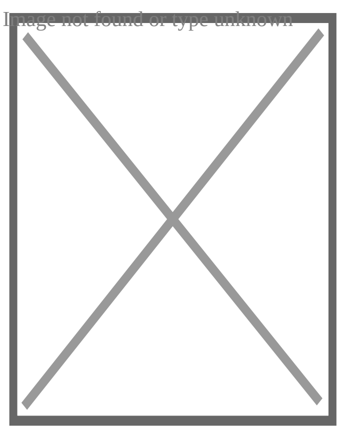
- Carbon products have been added to make concrete electrically conductive, for deicing purposes.[65]
- New research from Japan's University of Kitakyushu shows that a washed and dried recycled mix of used diapers can be an environmental solution to producing less landfill and using less sand in concrete production. A model home was built in Indonesia to test the strength and durability of the new diaper-cement composite.[66]

Production

[edit]



Concrete plant showing a concrete mixer being filled from ingredient silos



Concrete mixing plant in Birmingham, Alabama, in 1936

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. The usual method of placement is casting in formwork, which holds the mix in shape until it has set enough to hold its shape unaided.

Concrete plants come in two main types, ready-mix plants and central mix plants. A ready-mix plant blends all of the solid ingredients, while a central mix does the same but adds water. A central-mix plant offers more precise control of the concrete quality. Central mix plants must be close to the work site where the concrete will be used, since hydration begins at the plant.

A concrete plant consists of large hoppers for storage of various 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. The forms are containers that define the desired shape. Concrete formwork can be prepared in several ways, 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.

Interruption in pouring the concrete can cause the initially placed material to begin to set before the next batch is added on top. This creates a horizontal plane of weakness called a *cold joint* between the two batches.[67] 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.

Design mix

[edit]

Design mix ratios are decided by an engineer after analyzing the properties of the specific ingredients being used. Instead of using a 'nominal mix' of 1 part cement, 2 parts sand, and 4 parts aggregate, a civil engineer will custom-design a concrete mix to exactly meet the requirements of the site and conditions, setting material ratios and often designing an admixture package to fine-tune the properties or increase the performance envelope of the mix. Design-mix concrete can have very broad specifications that cannot be met with more basic nominal mixes, but the involvement of the engineer often increases the cost of the concrete mix.

Concrete mixes are primarily divided into nominal mix, standard mix and design mix.

Nominal mix ratios are given in volume of $\displaystyle \text{Cement : Sand : Aggregate}$ Image not found or type unknown . Nominal mixes are a simple, fast way of getting a basic idea of the properties of the finished concrete without having to perform testing in advance.

Various governing bodies (such as British Standards) define nominal mix ratios into a number of grades, usually ranging from lower compressive strength to higher compressive strength. The grades usually indicate the 28-day cure strength.[68]

Mixing

[edit]
See also: Volumetric concrete mixer and Concrete mixer

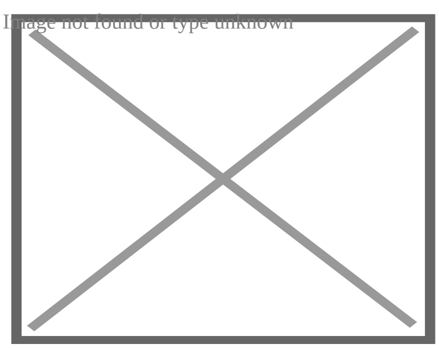
Thorough mixing is essential to produce uniform, high-quality concrete.

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.[69] The paste is generally mixed in a *high-speed*, shear-type mixer at a w/c (water to cement ratio) of 0.30 to 0.45 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.[70]

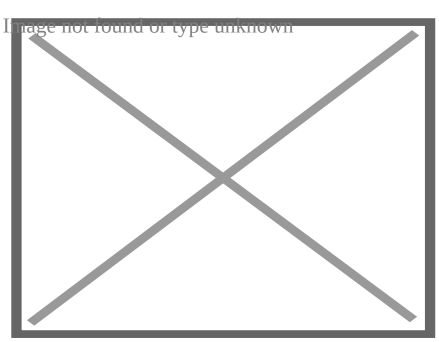
Resonant acoustic mixing has also been found effective in producing ultra-high performance cementitious materials, as it produces a dense matrix with low porosity.[71]

Sample analysis—workability

[edit]
Main article: Concrete slump test



Concrete floor of a parking garage being placed



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 (pouring, pumping, spreading, tamping, 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 or segregation of aggregates (when the cement and aggregates start to separate), with the resulting concrete having reduced quality. Changes in gradation can also affect workability of the concrete, although a wide range of gradation can be used for various applications.[72][73] An undesirable gradation can mean using a large aggregate that is too large for the size of the formwork, or which has too few smaller aggregate grades to serve to fill the gaps between the larger grades, or using too little or too much sand for the same reason, or using too little water, or too much cement, or even using jagged crushed stone instead of smoother round aggregate such as pebbles. Any combination of these factors and others may result in a mix which is too harsh, i.e., which does not flow or spread out smoothly, is difficult to get into the formwork, and which is difficult to surface finish.[74]

Workability can be measured by the concrete slump test, a simple measure of the plasticity of a fresh batch of concrete following the ASTM C 143 or EN 12350-2 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 (25 or 50 mm) out of one foot (300 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.[75] 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

[edit]

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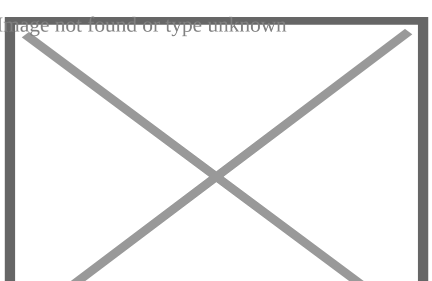


A concrete slab being kept hydrated during water curing by submersion (ponding)

Maintaining optimal conditions for cement hydration

[edit]

Concrete must be kept moist during curing in order to achieve optimal strength and durability.[76] During curing hydration occurs, allowing calcium-silicate hydrate (C-S-H) to form. Over 90% of a mix's final strength is typically reached within four weeks, with the remaining 10% achieved over years or even decades.[77] The conversion of calcium hydroxide in the concrete into calcium carbonate from absorption of CO_2 over several decades further strengthens the concrete and makes it more resistant to damage. This carbonation reaction, however, lowers the pH of the cement pore solution and can corrode the reinforcement bars.

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.[50] Addition of short-cut polymer fibers can improve (reduce) shrinkage-induced stresses during curing and increase early and ultimate compression strength.[78]

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 spalling, reduced strength, poor abrasion resistance and cracking.

Curing techniques avoiding water loss by evaporation

[edit]

During the curing period, concrete is ideally maintained at controlled temperature and humidity. To ensure full hydration during curing, concrete slabs are often sprayed with "curing compounds" that create a water-retaining film over the concrete. Typical films are made of wax or related hydrophobic compounds. After the concrete is sufficiently cured, the film is allowed to abrade from the concrete through normal use.[79]

Traditional conditions for curing involve spraying or ponding the concrete surface with water. The adjacent picture shows one of many ways to achieve this, ponding—submerging setting concrete in water and wrapping in plastic to prevent dehydration. Additional common curing methods include wet burlap and plastic sheeting covering the fresh concrete.

For higher-strength applications, accelerated curing techniques may be applied to the concrete. A common technique involves heating the poured concrete with steam, which serves to both keep it damp and raise the temperature so that the hydration process proceeds more quickly and more thoroughly.

Alternative types

[edit]
Main article: Types of concrete

Asphalt

[edit]
Main article: Asphalt concrete

Asphalt concrete (commonly called *asphalt*,[80] *blacktop*, or *pavement* in North America, and *tarmac*, *bitumen macadam*, or *rolled asphalt* in the United Kingdom and Ireland) is a composite material commonly used to surface roads, parking lots, airports, as well as the core of embankment dams.[81] Asphalt mixtures have been used in pavement construction since the beginning of the twentieth century.[82] It consists of mineral aggregate bound together with asphalt, laid in layers, and compacted. The process was refined and enhanced by Belgian inventor and U.S. immigrant Edward De Smedt.[83]

The terms *asphalt* (or *asphaltic*) *concrete*, *bituminous asphalt concrete*, and *bituminous mixture* are typically used only in engineering and construction documents, which define concrete as any composite material composed of mineral aggregate adhered with a binder. The abbreviation, *AC*, is sometimes used for *asphalt concrete* but can also denote *asphalt content* or *asphalt cement*, referring to the liquid asphalt portion of the composite material.

Graphene enhanced concrete

[edit]

Graphene enhanced concretes are standard designs of concrete mixes, except that during the cement-mixing or production process, a small amount of chemically engineered graphene (typically < 0.5% by weight) is added.[84][85] These enhanced graphene concretes are designed around the concrete application.

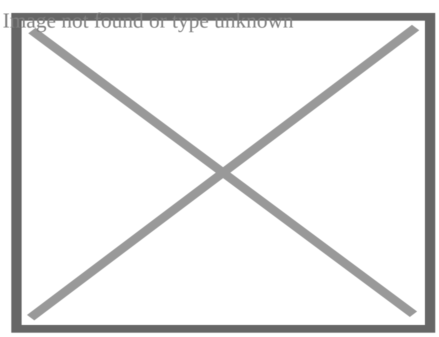
Microbial

[edit]

Bacteria such as *Bacillus pasteurii*, *Bacillus pseudofirmus*, *Bacillus cohnii*, *Sporosarcina pasteuri*, and *Arthrobacter crystallopoietes* increase the compression strength of concrete through their biomass. However some forms of bacteria can also be concrete-destroying.[86] Bacillus sp. CT-5. 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.[87] *Bacillus pasteurii* and *B. sphaericuscan* induce calcium carbonate precipitation in the surface of cracks, adding compression strength.[88]

Nanoconcrete

[edit]



Decorative plate made of Nano concrete with High-Energy Mixing (HEM)

Nanoconcrete (also spelled "nano concrete"' or "nano-concrete") is a class of materials that contains Portland cement particles that are no greater than 100 ?m[89] and particles of silica no greater than 500 ?m, which fill voids that would otherwise occur in normal concrete, thereby substantially increasing the material's strength.[90] It is widely used in foot and highway bridges where high flexural and compressive strength are indicated.[88]

Pervious

[edit]

Main article: 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 totaling approximately 15 to 25 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. Pervious concrete also permits rainwater to filter through roads and parking lots, to recharge aquifers, instead of contributing to runoff and flooding.[91]

Polymer

[edit]
Main article: Polymer concrete

Polymer concretes are mixtures of aggregate and any of various polymers and may be reinforced. The cement is costlier than lime-based cements, but polymer concretes nevertheless have advantages; they have significant tensile strength even without reinforcement, and they are largely impervious to water. Polymer concretes are frequently used for the repair and construction of other applications, such as drains.

Plant fibers

[edit]

Plant fibers and particles can be used in a concrete mix or as a reinforcement.[92][93][94] These materials can increase ductility but the lignocellulosic particles hydrolyze during concrete curing as a result of alkaline environment and elevated temperatures[95][96][97] Such process, that is difficult to measure,[98] can affect the properties of the resulting concrete.

Sulfur concrete

[edit]
Main article: Sulfur concrete

Sulfur concrete is a special concrete that uses sulfur as a binder and does not require cement or water.

Volcanic

[edit]

Volcanic concrete substitutes volcanic rock for the limestone that is burned to form clinker. It consumes a similar amount of energy, but does not directly emit carbon as a byproduct.[99] Volcanic rock/ash are used as supplementary cementitious materials in concrete to improve the resistance to sulfate, chloride and alkali silica reaction due to pore refinement.[100] Also, they are generally cost effective in comparison to other aggregates,[101] good for semi and light weight concretes,[101] and good for thermal and acoustic insulation.[101]

Pyroclastic materials, such as pumice, scoria, and ashes are formed from cooling magma during explosive volcanic eruptions. They are used as supplementary cementitious materials (SCM) or as aggregates for cements and concretes.[102] They have been extensively used since ancient times to produce materials for building applications. For example, pumice and other volcanic glasses were added as a natural pozzolanic material for mortars and plasters during the construction of the Villa San Marco in the Roman period (89 BC – 79 AD), which remain one of the best-preserved otium villae of the Bay of Naples in Italy.[103]

Waste light

[edit]
Main article: Waste light concrete

Waste light is a form of polymer modified concrete. The specific polymer admixture allows the replacement of all the traditional aggregates (gravel, sand, stone) by any mixture of solid waste materials in the grain size of 3–10 mm to form a low-compressive-strength (3–20 N/mm^2) product[104] for road and building construction. One cubic meter of waste light concrete contains 1.1–1.3 m^3 of shredded waste and no other aggregates.

Recycled Aggregate Concrete (RAC)

[edit]

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Recycled aggregate concretes are standard concrete mixes with the addition or substitution of natural aggregates with recycled aggregates sourced from construction and demolition wastes, disused pre-cast concretes or masonry. In most cases, recycled aggregate concrete results in higher water absorption levels by capillary action and permeation, which are the prominent determiners of the strength and durability of the resulting concrete. The increase in water absorption levels is mainly caused by the porous adhered mortar that exists in the recycled aggregates. Accordingly, recycled concrete aggregates that have been washed to reduce the quantity of mortar adhered to aggregates show lower water absorption levels compared to untreated recycled aggregates.

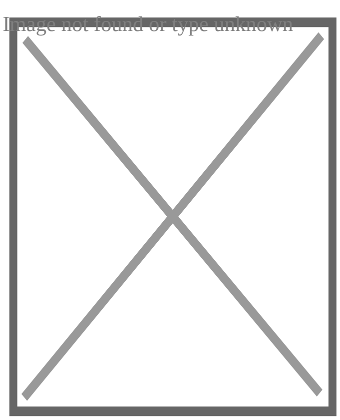
The quality of the recycled aggregate concrete is determined by several factors, including the size, the number of replacement cycles, and the moisture levels of the recycled aggregates. When the recycled concrete aggregates are crushed into coarser fractures, the mixed concrete shows better permeability levels, resulting in an overall increase in strength. In contrast, recycled masonry aggregates provide better qualities when crushed in finer fractures. With each generation of recycled concrete, the resulting compressive strength decreases.

Properties

[edit]
Main article: Properties of concrete

Concrete has relatively high compressive strength, but much lower tensile strength.[105] Therefore, 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.



Compression testing of a concrete cylinder

The ingredients affect the strengths of the material. Concrete strength values are usually specified as the lower-bound compressive strength of either a cylindrical or cubic specimen as determined by standard test procedures.

The strengths of concrete is dictated by its function. Very low-strength—14 MPa (2,000 psi) or less—concrete may be used when the concrete must be lightweight.[106] 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, 20 to 32 MPa (2,900 to 4,600 psi) concrete is often used. 40 MPa (5,800 psi) concrete is readily commercially available as a more durable, although more expensive, option. Higher-strength concrete is often used for larger civil projects.[107] Strengths above 40 MPa (5,800 psi) are often used for specific building elements. For example, the lower floor columns of high-rise concrete buildings may use concrete of 80 MPa (11,600 psi) or more, to keep the size of the columns small. Bridges may use long beams of high-strength concrete to lower the number of spans required.[108][109] 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 130 MPa (18,900 psi) have been used commercially for these reasons.[108]

Energy efficiency

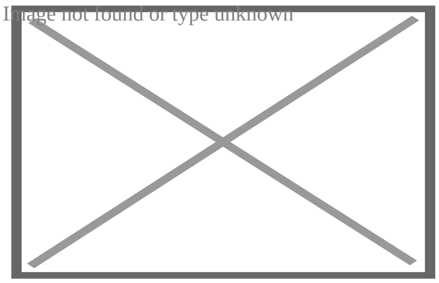
[edit]

The cement produced for making concrete accounts for about 8% of worldwide CO_2 emissions per year (compared to, *e.g.*, global aviation at 1.9%).[110][111] The two largest sources of CO_2 are produced by the cement manufacturing process, arising from (1) the decarbonation reaction of limestone in the cement kiln (T ? 950 °C), and (2) from the combustion of fossil fuel to reach the sintering temperature (T ? 1450 °C) of cement clinker in the kiln. The energy required for extracting, crushing, and mixing the raw materials (construction aggregates used in the concrete production, and also limestone and clay feeding the cement kiln) is lower. Energy requirement for transportation of ready-mix concrete is also lower because it is produced nearby the construction site from local resources, typically manufactured within 100 kilometers of the job site.[112] The overall embodied energy of concrete at roughly 1 to 1.5 megajoules per kilogram is therefore lower than for many structural and construction materials.[113]

Once in place, concrete offers a great energy efficiency over the lifetime of a building.[114] Concrete walls leak air far less than those made of wood frames.[115] 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.[116] 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.

Fire safety

[edit]



Boston City Hall (1968) is a Brutalist design constructed largely of precast and poured in place concrete.

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 required to resist more extreme forces.

Earthquake safety

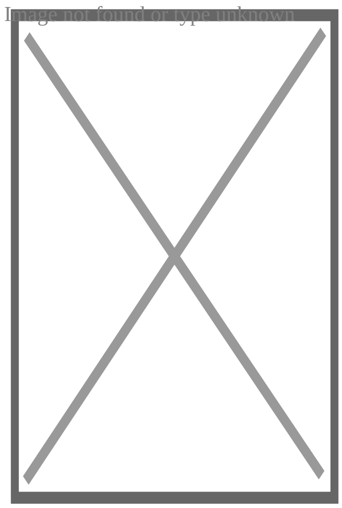
[edit]

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.[117] These risks can be reduced through seismic retrofitting of at-risk buildings, (e.g. school buildings in Istanbul, Turkey).[

118]

Construction

[edit]

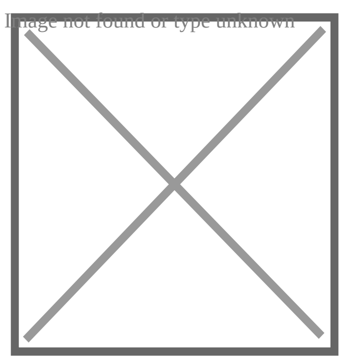


The City Court Building in Buffalo, New York

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.[119] Concrete is used more than any other artificial material in the world.[120] As of 2006, about 7.5 billion cubic meters of concrete are made each year, more than one cubic meter for every person on Earth.[121]

Reinforced

[edit]
Main article: Reinforced concrete



Christ the Redeemer statue in Rio de Janeiro, Brazil. It is made of reinforced concrete clad in a mosaic of thousands of triangular soapstone tiles.[122]

The use of reinforcement, in the form of iron was introduced in the 1850s by French industrialist François Coignet, and it was not until the 1880s that German civil engineer G. A. Wayss used steel as reinforcement. Concrete is a relatively brittle material that is strong under compression but less in tension. Plain, unreinforced concrete is unsuitable for many structures as it is relatively poor at withstanding stresses induced by vibrations, wind loading, and so on. Hence, to increase its overall strength, steel rods, wires, mesh or cables can be embedded in concrete before it is set. This reinforcement, often known as rebar, resists tensile forces.[123]

Reinforced concrete (RC) is a versatile composite and one of the most widely used materials in modern construction. It is made up of different constituent materials with very different properties that complement each other. In the case of reinforced concrete, the component materials are almost always concrete and steel. These two materials form a strong bond together and are able to resist a variety of applied forces, effectively acting as a single structural element.[124]

Reinforced concrete can be precast or cast-in-place (in situ) concrete, and is used in a wide range of applications such as; slab, wall, beam, column, foundation, and frame construction. Reinforcement is generally placed in areas of the concrete that are likely to be subject to tension, such as the lower portion of beams. Usually, there is a minimum of 50 mm cover, both above and below the steel reinforcement, to resist spalling and corrosion which can lead to structural instability.[123] Other types of non-steel reinforcement, such as Fibre-reinforced concretes are used for specialized applications, predominately as a means of controlling cracking.[124]

Precast

[edit]
Main article: Precast concrete

Precast concrete is concrete which is cast in one place for use elsewhere and is a mobile material. The largest part of precast production is carried out in the works of specialist suppliers, although in some instances, due to economic and geographical factors, scale of product or difficulty of access, the elements are cast on or adjacent to the construction site.[125] Precasting offers considerable advantages because it is carried out in a controlled environment, protected from the elements, but the downside of this is the contribution to greenhouse gas emission from transportation to the construction site.[124]

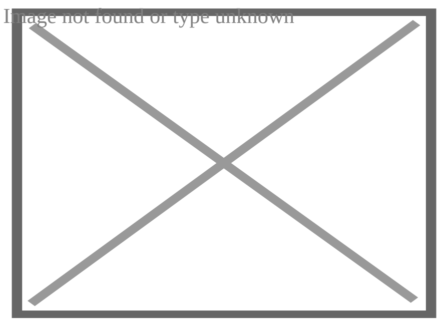
Advantages to be achieved by employing precast concrete:[125]

- Preferred dimension schemes exist, with elements of tried and tested designs available from a catalogue.
- Major savings in time result from manufacture of structural elements apart from the series of events which determine overall duration of the construction, known by planning engineers as the 'critical path'.
- Availability of Laboratory facilities capable of the required control tests, many being certified for specific testing in accordance with National Standards.

- Equipment with capability suited to specific types of production such as stressing beds with appropriate capacity, moulds and machinery dedicated to particular products.
- High-quality finishes achieved direct from the mould eliminate the need for interior decoration and ensure low maintenance costs.

Mass structures

[edit]
Main article: Mass concrete



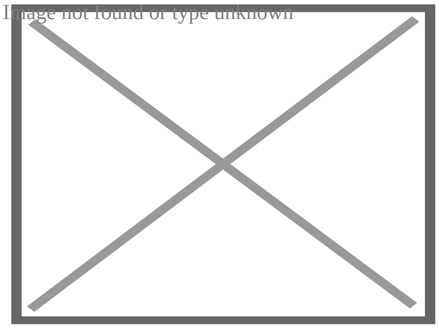
Aerial photo of reconstruction at Taum Sauk (Missouri) pumped storage facility in late November 2009. After the original reservoir failed, the new reservoir was made of roller-compacted concrete.

Due to cement's exothermic chemical reaction while setting up, large concrete structures such as dams, navigation locks, large mat foundations, and large breakwaters generate excessive heat during hydration and associated expansion. To mitigate these effects, *post-cooling*[126] is commonly applied during construction. An early example at Hoover Dam used 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.[126]

Another approach to mass concrete structures that minimizes cement's thermal by-product is the use of roller-compacted concrete, which uses a dry mix which has a much lower cooling requirement than conventional wet placement. It is deposited in thick layers as a semi-dry material then roller compacted into a dense, strong mass.

Surface finishes

[edit]
Main article: Decorative concrete



Black basalt polished concrete floor

Raw concrete surfaces tend to be porous and have a relatively uninteresting appearance. Many finishes can be applied to improve the appearance and preserve the surface against staining, water penetration, and freezing.

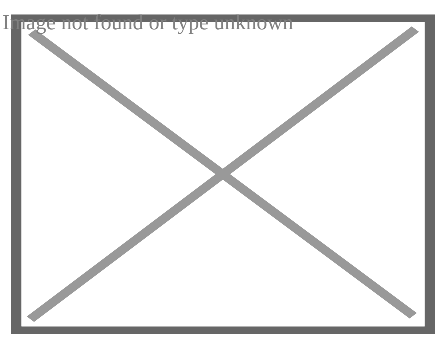
Examples of improved appearance include stamped concrete where the wet concrete has a pattern impressed on the surface, to give a paved, cobbled or brick-like effect, and may be accompanied with coloration. Another popular effect for flooring and table tops is polished concrete where the concrete is polished optically flat with diamond abrasives and sealed with polymers or other sealants.

Other finishes can be achieved with chiseling, or more conventional techniques such as painting or covering it with other materials.

The proper treatment of the surface of concrete, and therefore its characteristics, is an important stage in the construction and renovation of architectural structures.[127]

Prestressed

[edit]
Main article: Prestressed concrete



Stylized cacti decorate a sound/retaining wall in Scottsdale, Arizona

Prestressed concrete is a form of reinforced concrete that builds in compressive stresses during construction to oppose tensile stresses 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.

There are two different systems being used:[124]

- Pretensioned concrete is almost always precast, and contains steel wires (tendons) that are held in tension while the concrete is placed and sets around them.
- Post-tensioned concrete has ducts through it. After the concrete has gained strength, tendons are pulled through the ducts and stressed. The ducts are then filled with grout. Bridges built in this way have experienced considerable corrosion of the tendons, so external post-tensioning may now be used in which the tendons run along the outer surface of the concrete.

More than 55,000 miles (89,000 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. For more information see Brutalist architecture.

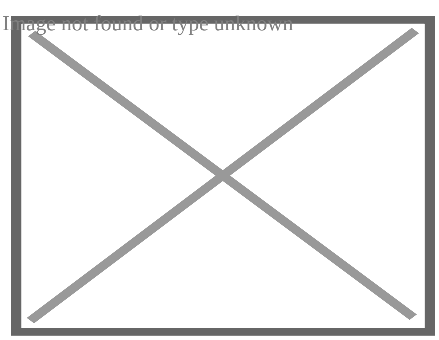
Placement

[edit]

Once mixed, concrete is typically transported to the place where it is intended to become a structural item. Various methods of transportation and placement are used depending on the distances involve, quantity needed, and other details of application. Large amounts are often transported by truck, poured free under gravity or through a tremie, or pumped through a pipe. Smaller amounts may be carried in a skip (a metal container which can be tilted or opened to release the contents, usually transported by crane or hoist), or wheelbarrow, or carried in toggle bags for manual placement underwater.

Cold weather placement

[edit]



Pohjolatalo, an office building made of concrete in the city center of Kouvola in Kymenlaakso, Finland

Extreme weather conditions (extreme heat or cold; windy conditions, and humidity variations) can significantly alter the quality of concrete. Many precautions are observed in cold weather placement.[128] Low temperatures significantly slow the chemical reactions involved in hydration of cement, thus affecting the strength development. Preventing freezing is the most important precaution, as formation of ice crystals can cause damage to the crystalline structure of the hydrated cement paste. If the surface of the concrete pour is insulated from the outside temperatures, the heat of hydration will prevent freezing.

The American Concrete Institute (ACI) definition of cold weather placement, ACI 306,[129] is:

- A period when for more than three successive days the average daily air temperature drops below 40 °F (~ 4.5 °C), and
- Temperature stays below 50 °F (10 °C) for more than one-half of any 24-hour period.

In Canada, where temperatures tend to be much lower during the cold season, the following criteria are used by CSA A23.1:

- When the air temperature is ? 5 °C, and
- When there is a probability that the temperature may fall below 5 °C within 24 hours of placing the concrete.

The minimum strength before exposing concrete to extreme cold is 500 psi (3.4 MPa). CSA A 23.1 specified a compressive strength of 7.0 MPa to be considered safe for exposure to freezing.

Underwater placement

[edit]
See also: Underwater construction

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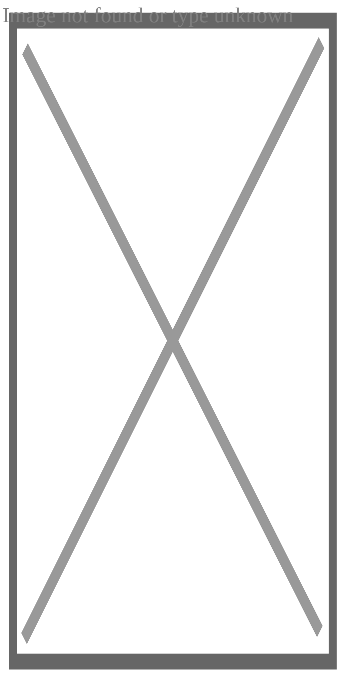

Assembled tremie placing concrete underwater

Concrete may be placed and cured underwater. Care must be taken in the placement method to prevent washing out the cement. Underwater placement methods include the tremie, pumping, skip placement, manual placement using toggle bags, and bagwork.[130]

A tremie is a vertical, or near-vertical, pipe with a hopper at the top used to pour concrete underwater in a way that avoids washout of cement from the mix due to turbulent water contact with the concrete while it is flowing. This produces a more reliable strength of the product. The toggle bag method is generally used for placing small quantities and for repairs. Wet concrete is loaded into a reusable canvas bag and squeezed out at the required place by the diver. Care must be taken to avoid washout of the cement and fines.

Underwater bagwork is the manual placement by divers of woven cloth bags containing dry mix, followed by piercing the bags with steel rebar pins to tie the bags together after every two or three layers, and create a path for hydration to induce curing, which can typically take about 6 to 12 hours for initial hardening and full hardening by the next day. Bagwork concrete will generally reach full strength within 28 days. Each bag must be pierced by at least one, and preferably up to four pins. Bagwork is a simple and convenient method of underwater concrete placement which does not require pumps, plant, or formwork, and which can minimise environmental effects from dispersing cement in the water. Prefilled bags are available, which are sealed to prevent premature hydration if stored in suitable dry conditions. The bags may be biodegradable.[131]

Grouted aggregate is an alternative method of forming a concrete mass underwater, where the forms are filled with coarse aggregate and the voids then completely filled from the bottom by displacing the water with pumped grout.[130]

Roads

[edit]

Concrete roads are more fuel efficient to drive on,[132] more reflective and last significantly longer than other paving surfaces, yet have a much smaller market share than other paving solutions. Modern-paving methods and design practices have changed the economics of concrete paving, so that a well-designed and placed concrete pavement will be less expensive on initial costs and significantly less expensive over the life cycle. Another major benefit is that pervious concrete can be used, which eliminates the need to place storm drains near the road, and reducing the need for slightly sloped roadway to help rainwater to run off. No longer requiring discarding rainwater through use of drains also means that less electricity is needed (more pumping is otherwise needed in the water-distribution system), and no rainwater gets polluted as it no longer mixes with polluted water. Rather, it is immediately absorbed by the ground.[*citation needed*]

Tube forest

[edit]

Cement molded into a forest of tubular structures can be 5.6 times more resistant to cracking/failure than standard concrete. The approach mimics mammalian cortical bone that features elliptical, hollow osteons suspended in an organic matrix, connected by relatively weak "cement lines". Cement lines provide a preferable in-plane crack path. This design fails via a "stepwise toughening mechanism". Cracks are contained within the tube, reducing spreading, by dissipating energy at each tube/step.[133]

Environment, health and safety

[edit]
Main article: Environmental impact of concrete

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The manufacture and use of concrete produce a wide range of environmental, economic and social impacts.

Health and safety

[edit]
See also: Occupational dust exposure § Construction

Concrete dust emission from the use of power tool

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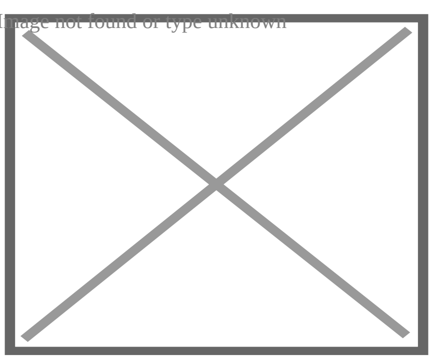


Recycled crushed concrete, to be reused as granular fill, is loaded into a semi-dump truck

Grinding of concrete can produce hazardous dust. Exposure to cement dust can lead to issues such as silicosis, kidney disease, skin irritation and similar effects. The U.S. National Institute for Occupational Safety and Health in the United States recommends attaching local exhaust ventilation shrouds to electric concrete grinders to control the spread of this dust. In addition, the Occupational Safety and Health Administration (OSHA) has placed more stringent regulations on companies whose workers regularly come into contact with silica dust. An updated silica rule, which OSHA put into effect 23 September 2017 for construction companies, restricted the amount of breathable crystalline silica workers could legally come into contact with to 50 micro grams per cubic meter of air per 8-hour workday. That same rule went into effect 23 June 2018 for general industry, hydraulic fracturing and maritime. That deadline was extended to 23 June 2021 for engineering controls in the hydraulic fracturing industry. Companies which fail to meet the tightened safety regulations can face financial charges and extensive penalties. The presence of some substances in concrete, including useful and unwanted additives, can cause health concerns due to toxicity and radioactivity. Fresh concrete (before curing is complete) is highly alkaline and must be handled with proper protective equipment.

Cement

[edit]

A major component of concrete is cement, a fine powder used mainly to bind sand and coarser aggregates together in concrete. Although a variety of cement types exist, the most common is "Portland cement", which is produced by mixing clinker with smaller quantities of other additives such as gypsum and ground limestone. The production of clinker, the main constituent of cement, is responsible for the bulk of the sector's greenhouse gas emissions, including both energy intensity and process emissions.[134]

The cement industry is one of the three primary producers of carbon dioxide, a major greenhouse gas – the other two being energy production and transportation industries. On average, every tonne of cement produced releases one tonne of CO_2 into the atmosphere. Pioneer cement manufacturers have claimed to reach lower carbon intensities, with 590 kg of CO_2eq per tonne of cement produced.[135] The emissions are due to combustion and calcination processes,[136] which roughly account for 40% and 60% of the greenhouse gases, respectively. Considering that cement is only a fraction of the constituents of concrete, it is estimated that a tonne of concrete is responsible for emitting about 100–200 kg of CO_2.[137][138] Every year more than 10 billion tonnes of concrete are used worldwide.[138] In the coming years, large quantities of concrete will continue to be used, and the mitigation of CO_2 emissions from the sector will be even more critical.

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 dust released by building demolition and natural disasters can be a major source of dangerous air pollution. Concrete is a contributor to the urban heat island effect, though less so than asphalt.

Climate change mitigation

[edit]

Reducing the cement clinker content might have positive effects on the environmental life-cycle assessment of concrete. Some research work on reducing the cement clinker content in concrete has already been carried out. However, there exist different research strategies. Often replacement of some clinker for large amounts of slag or fly ash was investigated based on conventional concrete technology. This could lead to a waste of scarce raw materials such as slag and fly ash. The aim of other research activities is the efficient use of cement and reactive materials like slag and fly ash in concrete based on a modified mix design approach.[139]

The embodied carbon of a precast concrete facade can be reduced by 50% when using the presented fiber reinforced high performance concrete in place of typical reinforced concrete cladding.[140] Studies have been conducted about commercialization of low-carbon concretes. Life cycle assessment (LCA) of low-carbon concrete was investigated according to the ground granulated blast-furnace slag (GGBS) and fly ash (FA) replacement ratios. Global warming potential (GWP) of GGBS decreased by 1.1 kg CO_2 eq/m^3, while FA decreased by 17.3 kg CO_2 eq/m^3 when the mineral admixture replacement ratio was increased by 10%. This study also compared the compressive strength properties of binary blended low-carbon concrete according to the replacement ratios, and the applicable range of mixing proportions was derived.[141]

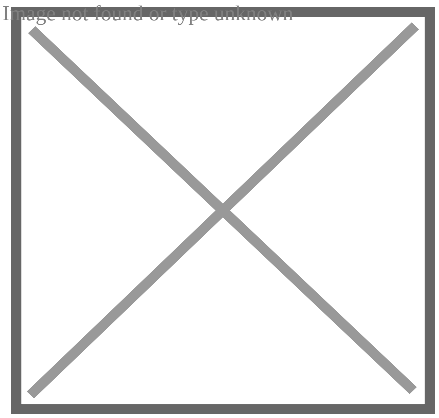
Climate change adaptation

[edit]

High-performance building materials will be particularly important for enhancing resilience, including for flood defenses and critical-infrastructure protection.[142] Risks to infrastructure and cities posed by extreme weather events are especially serious for those places exposed to flood and hurricane damage, but also where residents need protection from extreme summer temperatures. Traditional concrete can come under strain when exposed to humidity and higher concentrations of atmospheric CO_2. While concrete is likely to remain important in applications where the environment is challenging, novel, smarter and more adaptable materials are also needed.[138][143]

End-of-life: degradation and waste

[edit]



The Tunkhannock Viaduct in northeastern Pennsylvania opened in 1915 and is still in regular use today

This paragraph is an excerpt from Concrete degradation.[edit]
Concrete degradation may have many different causes. Concrete is mostly damaged by the corrosion of reinforcement bars due to the carbonatation of hardened cement paste or chloride attack under wet conditions. Chemical damage is caused by the formation of expansive products produced by chemical reactions (from carbonatation, chlorides, sulfates and distillate water), by aggressive chemical species present in groundwater and seawater (chlorides, sulfates, magnesium ions), or by microorganisms (bacteria, fungi...) Other damaging processes can also involve calcium leaching by water infiltration, physical phenomena initiating cracks formation and propagation, fire or radiant heat, aggregate expansion, sea water effects, leaching, and erosion by fast-flowing water.[144]

Recycling

[edit]

This paragraph is an excerpt from Concrete recycling.[edit]
Concrete recycling is the use of rubble from demolished concrete structures. Recycling is cheaper and more ecological than trucking rubble to a landfill.[145] Crushed rubble can be used for road gravel, revetments, retaining walls, landscaping gravel, or raw material for new concrete. Large pieces can be used as bricks or slabs, or incorporated with new concrete into structures, a material called urbanite.[146][147]

There have been concerns about the recycling of painted concrete due to possible lead content. Studies have indicated that recycled concrete exhibits lower strength and durability compared to concrete produced using natural aggregates.[148][149][150][151] This deficiency can be addressed by incorporating supplementary materials such as fly ash into the mixture.[152]

World records

[edit]

The world record for the largest concrete pour in a single project is the Three Gorges Dam in Hubei Province, China by the Three Gorges Corporation. The amount of concrete used in the construction of the dam is estimated at 16 million cubic meters over 17 years. The previous record was 12.3 million cubic meters held by Itaipu hydropower station in Brazil.[153][154][155]

The world record for concrete pumping was set on 7 August 2009 during the construction of the Parbati Hydroelectric Project, near the village of Suind, Himachal Pradesh, India, when the concrete mix was pumped through a vertical height of 715 m (2,346 ft).[156][157]

The Polavaram dam works in Andhra Pradesh on 6 January 2019 entered the Guinness World Records by pouring 32,100 cubic metres of concrete in 24 hours.[158] The world record for the largest continuously poured concrete raft was achieved in August 2007 in Abu Dhabi by contracting firm Al Habtoor-CCC Joint Venture and the concrete supplier is Unibeton Ready Mix.[159][160] The pour (a part of the foundation for the Abu Dhabi's Landmark Tower) was 16,000 cubic meters of concrete poured within a two-day period.[161] The previous record, 13,200 cubic meters poured in 54 hours despite a severe tropical storm requiring the site to be covered with tarpaulins to allow work to continue, was achieved in 1992 by joint Japanese and South Korean consortiums Hazama Corporation and the Samsung C&T Corporation for the construction of the Petronas Towers in Kuala Lumpur, Malaysia.[162]

The world record for largest continuously poured concrete floor was completed 8 November 1997, in Louisville, Kentucky by design-build firm EXXCEL Project Management. The monolithic placement consisted of 225,000 square feet (20,900 m^2) of concrete placed in 30 hours, finished to a flatness tolerance of F_F 54.60 and a levelness tolerance of F_L 43.83. This surpassed the previous record by 50% in total volume and 7.5% in total area.[163][164]

The record for the largest continuously placed underwater concrete pour was completed 18 October 2010, in New Orleans, Louisiana by contractor C. J. Mahan Construction Company, LLC of Grove City, Ohio. The placement consisted of 10,251 cubic yards of concrete placed in 58.5 hours using two concrete pumps and two dedicated concrete batch plants. Upon curing, this placement allows the 50,180-square-foot (4,662 m^2) cofferdam to be dewatered approximately 26 feet (7.9 m) below sea level to allow the construction of the Inner Harbor Navigation Canal Sill & Monolith Project to be completed in the dry.[165]

Art

[edit]

Concrete is used as an artistic medium.[*citation needed*] Its appearance is also imitated in other media: for example Congolese artist Sardoine Mia creates canvases that look like concrete surfaces.[166]

See also

[edit]

- Concrete leveling – Process to level concrete by levelling its underlying foundation
- Concrete mixer – Device that combines cement, aggregate, and water to form concrete
- Concrete masonry unit – Standard-sized block used in construction
- Concrete plant – Equipment that combines various ingredients to form concrete
- Eurocode 2: Design of concrete structures
- Heavy metals – Loosely defined subset of elements that exhibit metallic properties
- Hempcrete – Biocomposite material used for construction and insulation
- Particulates – Microscopic solid or liquid matter suspended in the Earth's atmosphere
- Schmidt hammer – Type of measuring instrument
- Syncrete – Synthetic form of concrete
- Thermal integrity profiling – Method used to test concrete

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Further reading

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- "The world's growing problem with concrete, the world's most destructive material" (Video). BBC Reel. 6 March 2023.

External links

[edit]

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Wikimedia Commons has media related to ***Concrete***.

- Advantage and Disadvantage of Concrete
- *Dunning, Brian (4 January 2022). "Skeptoid #813: Why You Need to Care About Concrete". Skeptoid. Retrieved 14 May 2022.*
- Getting Buried in Concrete to Explain How It Works on YouTube
- Release of ultrafine particles from three simulated building processes
- Concrete: The Quest for Greener Alternatives

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Road hierarchy

Limited-access

- Bicycle highway
- Freeway / Motorway
- Dual carriageway / Divided highway / Expressway
- Elevated highway

By country

- Australia
- Belgium
- Brazil
- Canada
- China
- Croatia
- Czech Republic
- Germany
- Greece
- Hong Kong
- India
- Ireland
- Italy
- Nepal
- Pakistan
- Poland
- Portugal
- Spain
- Taiwan
- United Kingdom
- United States

Types of road

Main roads

- Arterial road
- Collector road
- County highway
- Express–collector setup
- Farm-to-market road
- Highway
- Link road
- Two-lane expressway
- 2+1 road
- 2+2 road
- Parkway
- Ring road
- Trunk road
- Highway systems by country

- Alley
- Avenue
- Back road
- Bicycle boulevard
- Boulevard

Road junctions

- **Interchanges (grade-separated)**
  - Cloverleaf
  - Diamond
  - Free-flow
  - Directional T
  - Diverging diamond
  - Parclo
  - Raindrop
  - Roundabout
  - Single-point urban (SPUI)
  - Stack
  - Three-level diamond
  - Trumpet
- **Intersections (at-grade)**
  - 3-way junction
  - Bowtie
  - Box junction
  - Channelization
  - Continuous flow
  - Hook turn
  - Jughandle
  - Michigan left
  - Offset T-intersection
  - Protected intersection
  - Quadrant roadway
  - Right-in/right-out (RIRO)
  - Roundabout
  - Seagull intersection
  - Split intersection
  - Superstreet
  - Texas U-turn
  - Turnaround

Surfaces

- Asphalt concrete
- Bioasphalt
- Brick
- Chipseal
- Cobblestone
- Concrete
    - Reinforced concrete
- Corduroy
- Crocodile cracking
- Crushed stone
- Diamond grinding of pavement
- Dirt
- Full depth recycling
- Glassphalt
- Gravel
- Ice
- Macadam
- Pavement milling
- Permeable
- Plank
- Plastic
- Rubberized asphalt
- Sealcoat
- Sett
- Stamped asphalt
- Tarmac
- Texture

Road safety factors

Road and environment

- Aquaplaning
- Avalanche
- Black ice
- Bleeding
- Crosswind
- Dead Man's Curve
- Expansion joint
- Fog
- Ford
- Hairpin turn
- Level crossing
- Manhole cover
- Oil spill
- Oversize load
- Pothole
- Road debris
- Road slipperiness
- Road train
- Roadkill
- Rockfall
- Rut
- Snow squall
- Speed bump
- Storm drain
- Traffic light
- Traffic sign
- Washboarding
- Washout
- Whiteout

Human factors

- Driver's education
- Driving under the influence
- Drowsy driving
- Road rage
- Single-vehicle crash

Vehicles

- Airbag
- Automotive safety
- Crumple zone
- Seat belt
- Risk compensation (road transport)
- Underride guard

Space and time allocation	◦ Barrier transfer machine ◦ Bike lane ◦ Climbing lane ◦ Complete streets ◦ Contraflow lane ◦ Contraflow lane reversal ◦ High-occupancy toll lane ◦ High-occupancy vehicle lane ◦ Lane ◦ Living street ◦ Managed lane ◦ Median / Central reservation ◦ Motorcycle lane ◦ Passing lane ◦ Pedestrian crossing ◦ Pedestrian zone ◦ Refuge island ◦ Reversible lane ◦ Road diet ◦ Road verge ◦ Runaway truck ramp ◦ Shared space ◦ Sidewalk / Pavement ◦ Shoulder ◦ Street-running railway ◦ Traffic calming ◦ Traffic directionality ◦ Traffic island ◦ Traffic lanes ◦ Traffic signal preemption ◦ Truck bypass ◦ Unused highway ◦ Wide outside lane ◦ Woonerf

Demarcation	◦ Bollard ◦ Botts' dots ◦ Cable barrier ◦ Cat's eye (road) ◦ Concrete step barrier ◦ Constant-slope barrier ◦ Curb ◦ F-shape barrier ◦ Guard rail ◦ Jersey barrier ◦ Kassel kerb ◦ Noise barrier ◦ Raised pavement marker ◦ Road surface marking ◦ Rumble strip ◦ Traffic barrier ◦ Traffic cone
Structures	◦ Bridge ◦ Causeway ◦ Overpass / Flyover ◦ Underpass / Tunnel
Performance indicators	◦ Pavement condition index ◦ International roughness index ◦ Present serviceability index ◦ Pavement performance modeling ◦ Granular base equivalency

- Glossary of road transport terms
- Road types by features
- Template:Traffic signs

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Stonemasonry

Types	◦ Ashlar ◦ Rustication ◦ Carving ◦ Dry stone ◦ Letter cutting ◦ Masonry ◦ Post-tensioned stone ◦ Massive precut stone ◦ Monumental ◦ Rubble ◦ Sculpture ◦ Slipform ◦ Snecked

Materials	◦ Artificial stone
	◦ Brick
	◦ Cast stone
	◦ Decorative stones
	◦ Dimension stone
	◦ Fieldstone
	◦ Flagstone
	◦ Gabion
	◦ Granite
	◦ Grout
	◦ Lime mortar
	◦ Limestone
	◦ Marble
	    ◦ Types
	◦ Mortar
	◦ Sandstone
	    ◦ List
	◦ Slate
	◦ Stone veneer

Tools	◦ Angle grinder ◦ Bush hammer ◦ Ceramic tile cutter ◦ Chisel ◦ Diamond blade ◦ Lewis (lifting appliance) ◦ Trowel ◦ Non-explosive demolition agents ◦ Plug and feather ◦ Stonemason's hammer ◦ Straightedge
Techniques	◦ Flaming ◦ Flushwork ◦ Knapping ◦ Polygonal masonry ◦ Repointing ◦ Scabbling ◦ Tuckpointing ◦ Veneer ◦ Brickwork ◦ Wythe
Products	◦ Castle ◦ Hardstone carving ◦ Headstone (Footstone) ◦ Mosaic ◦ Sculpture ◦ Stone wall ◦ Machicolation
Organizations	◦ International Union of Bricklayers and Allied Craftworkers ◦ Master of Work to the Crown of Scotland ◦ Mason Contractors Association of America ◦ Operative Plasterers' and Cement Masons' International Association ◦ Worshipful Company of Masons

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Concrete

History

- Ancient Roman architecture
- Roman architectural revolution
- Roman concrete
- Roman engineering
- Roman technology

Composition

- Cement
  - Calcium aluminate
  - Energetically modified
  - Portland
  - Rosendale
- Water
- Water–cement ratio
- Aggregate
- Reinforcement
- Fly ash
- Ground granulated blast-furnace slag
- Silica fume
- Metakaolin

Production

- Plant
- Concrete mixer
- Volumetric mixer
- Reversing drum mixer
- Slump test
- Flow table test
- Curing
- Concrete cover
- Cover meter
- Rebar

Construction	◦ Precast ◦ Cast-in-place ◦ Formwork ◦ Climbing formwork ◦ Slip forming ◦ Screed ◦ Power screed ◦ Finisher ◦ Grinder ◦ Power trowel ◦ Pump ◦ Float ◦ Sealer ◦ Tremie
Science	◦ Properties ◦ Durability ◦ Degradation ◦ Environmental impact ◦ Recycling ◦ Segregation ◦ Alkali–silica reaction

Types	- AstroCrete
	- Fiber-reinforced
	- Filigree
	- Foam
	- Lunarcrete
	- Mass
	- Nanoconcrete
	- Pervious
	- Polished
	- Polymer
	- Prestressed
	- Ready-mix
	- Reinforced
	- Roller-compacting
	- Self-consolidating
	- Self-leveling
	- Sulfur
	- Tabby
	- Translucent
	- Waste light
	- Aerated
	    - AAC
	    - RAAC

Applications	- Slab
	    - waffle
	    - hollow-core
	    - voided biaxial
	    - slab on grade
	- Concrete block
	- Step barrier
	- Roads
	- Columns
	- Structures

Organizations	- American Concrete Institute - Concrete Society - Institution of Structural Engineers - Indian Concrete Institute - Nanocem - Portland Cement Association - International Federation for Structural Concrete

Standards

- Eurocode 2
- EN 197-1
- EN 206-1
- EN 10080

See also

- Hempcrete

- Image not found or type unknown Category:Concrete

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National

- Germany
- United States
- France
- BnF data
- Japan
- Czech Republic
- Israel

Other

- NARA

About Landscape design

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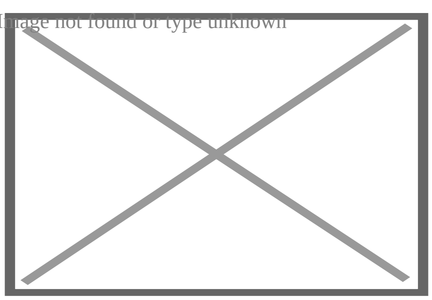


Central Park in Manhattan, the first landscaped urban park in the United States

Landscape design is an independent profession and a design and art tradition, practiced by landscape designers, combining nature and culture. In contemporary practice, landscape design bridges the space between landscape architecture and garden design.[1]

Design scope

[edit]

Landscape design focuses on both the integrated master landscape planning of a property and the specific garden design of landscape elements and plants within it. The practical, aesthetic, horticultural, and environmental sustainability are also components of landscape design, which is often divided into hardscape design and softscape design. Landscape designers often collaborate with related disciplines such as architecture, civil engineering, surveying, landscape contracting, and artisan specialties.

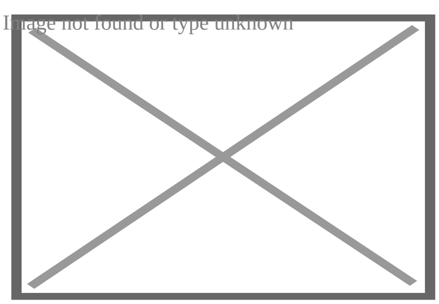
Design projects may involve two different professional roles: landscape design and landscape architecture.

- Landscape design typically involves artistic composition and artisanship, horticultural finesse and expertise, and emphasis on detailed site involvement from conceptual stages through to final construction.
- Landscape architecture focuses more on urban planning, city and regional parks, civic and corporate landscapes, large scale interdisciplinary projects, and delegation to contractors after completing designs.

There can be a significant overlap of talent and skill between the two roles, depending on the education, licensing, and experience of the professional. Both landscape designers and landscape architects practice landscape design.[2]

Design approach

[edit]



Autumn colours at Stourhead gardens

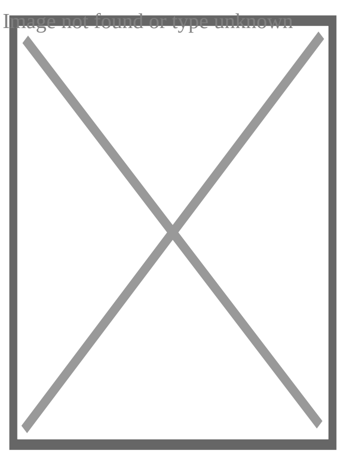
The landscape design phase consists of research, gathering ideas, and setting a plan. Design factors include objective qualities such as: climate and microclimates; topography and orientation, site drainage and groundwater recharge; municipal and resource building codes; soils and irrigation; human and vehicular access and circulation; recreational amenities (i.e., sports and water); furnishings and lighting; native plant habitat botany when present; property safety and security; construction detailing; and other measurable considerations.

Design factors also include subjective qualities such as genius loci (the special site qualities to emphasize); client's needs and preferences; desirable plants and elements to retain on site, modify, or replace, and that may be available for borrowed scenery from beyond; artistic composition from perspectives of both looking upon and observing from within; spatial development and definition – using lines, sense of scale, and balance and symmetry; plant palettes; and artistic focal points for enjoyment. There are innumerable other design factors and considerations brought to the complex process of designing a garden that is beautiful, well-functioning, and that thrives over time.

The up-and-coming practice of online landscape design allows professional landscapers to remotely design and plan sites through manipulation of two-dimensional images without ever physically visiting the location. Due to the frequent lack of non-visual, supplementary data such as soil assessments and pH tests, online landscaping necessarily must focus on incorporating only plants which are tolerant across many diverse soil conditions.

Training

[edit]



André Le Nôtre

Historically, landscape designers trained by apprenticing—such as André Le Nôtre, who apprenticed with his father before designing the Gardens of Versailles—to accomplished masters in the field, with the titular name varying and reputation paramount for a career. The professional section of garden designers in Europe and the Americas went by the name "Landscape Gardener". In the 1890s, the distinct classification of landscape architect was created, with educational and licensing test requirements for using the title legally. Beatrix Farrand, the sole woman in the founding group, refused the title preferring Landscape Gardener. Matching the client and technical needs of a project, and the appropriate practitioner with talent, legal qualifications, and experienced skills, surmounts title nomenclature.[*citation needed*]

Institutional education in landscape design appeared in the early 20th century. Over time it became available at various levels. Ornamental horticulture programs with design components are offered at community college and universities within schools of agriculture or horticulture, with some beginning to offer garden or landscape design certificates and degrees. Departments of landscape architecture are located within university schools of architecture or environmental design, with undergraduate and graduate degrees offered. Specialties and minors are available in horticultural botany, horticulture, natural resources, landscape engineering, construction management, fine and applied arts, and landscape design history. Traditionally, hand-drawn drawings documented the design and position of features for construction, but Landscape design software is frequently used now.[*citation needed*]

Other routes of training are through informal apprenticeships with practicing landscape designers, landscape architects, landscape contractors, gardeners, nurseries and garden centers, and docent programs at botanical and public gardens. Since the landscape designer title does not have a college degree or licensing requirements to be used, there is a very wide range of sophistication, aesthetic talent, technical expertise, and specialty strengths to be responsibly matched with specific client and project requirements.[*citation needed*]

Gardening

[edit]

Many landscape designers have an interest and involvement with gardening, personally or professionally. Gardens are dynamic and not static after construction and planting are completed, and so in some ways are "never done". Involvement with landscape management and direction of the ongoing garden direction, evolution, and care depend on the professional's and client's needs and inclinations. As with the other interrelated landscape disciplines, there can be an overlap of services offered under the titles of landscape designer or professional gardener.[2]

See also

[edit]

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Wikimedia Commons has media related to ***Landscape design***.

- Landscape design software
- Concrete landscape curbing
- Landscape assessment
- Landscape planning
- Space in landscape design

References

[edit]

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2. ^ ***a b*** *"Question & Answer". ASLA. Retrieved 2016-05-17.*

Design

- Outline
- Designer

Disciplines

Communication design	Advertising
	Book design
	Brand design
	Exhibit design
	Film title design
	Graphic design
	    Motion
	    Postage stamp design
	    Print design
	Illustration
	Information design
	Instructional design
	News design
	Photography
	Retail design
	Signage / Traffic sign design
	Typography / Type design
	Video design
	Visual merchandising

Environmental design	Architecture
	Architectural lighting design
	Building design
	    Passive solar
	Ecological design
	Environmental impact design
	Garden design
	    Computer-aided
	Healthy community design
	Hotel design
	Interior architecture
	Interior design
	    EID
	Keyline design
	Landscape architecture
	    Sustainable
	Landscape design
	Spatial design
	Urban design

	Automotive design Automotive suspension design CMF design Corrugated box design Electric guitar design

Approaches

- Active
- Activity-centered
- Adaptive web
- Affective
- Brainstorming
- By committee
- By contract
- C-K theory
- Closure
- Co-design
- Concept-oriented
- Configuration
- Contextual
- Continuous
- Cradle-to-cradle
- Creative problem-solving
- Creativity techniques
- Critical
    - Design fiction
- Defensive
- Design–bid–build
- Design–build
    - architect-led
- Diffuse
- Domain-driven
- Ecological design
- Energy neutral
- Engineering design process
    - Probabilistic design
- Ergonomic
- Error-tolerant
- Evidence-based
- Fault-tolerant
- Framework-oriented
- For assembly
- For behaviour change
- For manufacturability
- For Six Sigma
- For testing
- For the environment
- For X
- Functional
- Generative
- Geodesign
- HCD
- High-level
- Hostile

- **Tools**
- **Intellectual property**
- **Organizations**
- **Awards**

Tools	◦ AAD
	◦ Architectural model
	◦ Blueprint
	◦ Comprehensive layout
	◦ CAD
	    ◦ CAID
	    ◦ Virtual home design software
	◦ CAutoD
	◦ Design quality indicator
	◦ Electronic design automation
	◦ Flowchart
	◦ Mockup
	◦ Design specification
	◦ Prototype
	◦ Sketch
	◦ Storyboard
	◦ Technical drawing
	◦ HTML editor
	◦ Website wireframe

Intellectual property	◦ Clean-room design ◦ Community design ◦ Design around ◦ Design infringement ◦ Design patent ◦ Fashion design copyright ◦ *Geschmacksmuster* ◦ Industrial design rights ◦ European Union
Organizations	◦ American Institute of Graphic Arts ◦ Chartered Society of Designers ◦ Design and Industries Association ◦ Design Council ◦ International Forum Design ◦ Design Research Society
	◦ European Design Award ◦ German Design Award ◦ Good Design Award (Museum of Modern Art)

Related topics

- Agile
- Concept art
- Conceptual design
- Creative industries
- Cultural icon
- .design
- Dominant design
- Enterprise architecture
- Form factor
- Futures studies
- Indie design
- Innovation management
- Intelligent design
- Lean startup
- New product development
- OODA loop
- Philosophy of design
- Process simulation
- Reference design
- Slow design
- STEAM fields
- Unintelligent design
- Visualization
- Wicked problem

- Design attributes
- brief
- change
- classic
- competition
  - architectural
  - student
- director
- education
- elements
- engineer
- firm
- history
- knowledge
- language
- life
- load
- museum
- optimization
- paradigm
- principles
- rationale

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About landscape architecture

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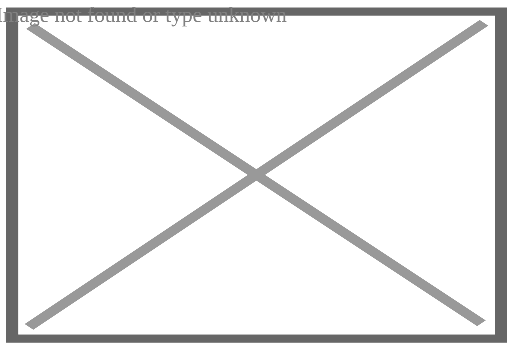

Stourhead in Wiltshire, England, designed by Henry Hoare (1705–1785), "the first landscape gardener, who showed in a single work, genius of the highest order"[1]

Landscape architecture is the design of outdoor areas, landmarks, and structures to achieve environmental, social-behavioural, or aesthetic outcomes.[2] It involves the systematic design and general engineering of various structures for construction and human use, investigation of existing social, ecological, and soil conditions and processes in the landscape, and the design of other interventions that will produce desired outcomes.

The scope of the profession is broad and can be subdivided into several sub-categories including professional or licensed landscape architects who are regulated by governmental agencies and possess the expertise to design a wide range of structures and landforms for human use; landscape design which is not a licensed profession; site planning; stormwater management; erosion control; environmental restoration; public realm, parks, recreation and urban planning; visual resource management; green infrastructure planning and provision; and private estate and residence landscape master planning and design; all at varying scales of design, planning and management. A practitioner in the profession of landscape architecture may be called a landscape architect; however, in jurisdictions where professional licenses are required it is often only those who possess a landscape architect license who can be called a landscape architect.

Definition of landscape architecture

[edit]

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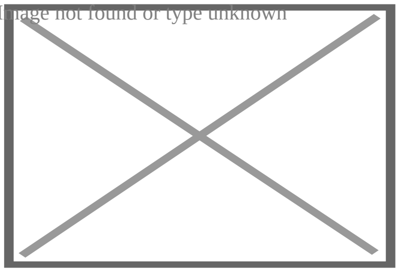

A canal design focused on esthetical landscape architecture in Stockholm, Sweden.

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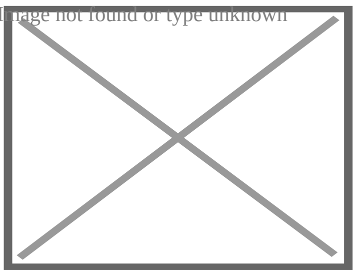


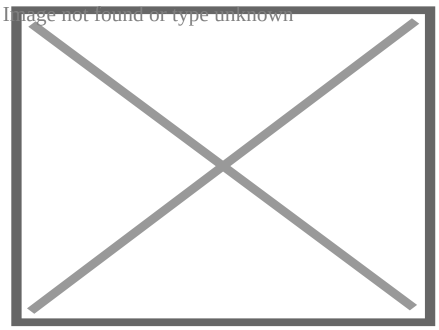
A river with concrete walls like those of a flood control channel, a historic flood-control measure using landscape engineering in Houston, Texas. Such channelling, intended to be strictly functional, may make flooding worse, by speeding the flow instead of spreading the pulse of floodwater.[3][4][5]

Modern landscape architecture is a multi-disciplinary field, incorporating aspects of urban design, architecture, geography, ecology, civil engineering, structural engineering, horticulture, environmental psychology, industrial design, soil sciences, botany, and fine arts. The activities of a landscape architect can range from the creation of public parks and parkways to site planning for campuses and corporate office parks; from the design of residential estates to the design of civil infrastructure; and from the management of large wilderness areas to reclamation of degraded landscapes such as mines or landfills. Landscape architects work on structures and external spaces in the landscape aspect of the design – large or small, urban, suburban and rural, and with "hard" (built) and "soft" (planted) materials, while integrating ecological sustainability.

The most valuable contribution can be made at the first stage of a project to generate ideas with technical understanding and creative flair for the design, organization, and use of spaces. The landscape architect can conceive the overall concept and prepare the master plan, from which detailed design drawings and technical specifications are prepared. They can also review proposals to authorize and supervise contracts for the construction work. Other skills include preparing design impact assessments, conducting environmental assessments and audits, and serving as an expert witness at inquiries on land use issues. The majority of their time will most likely be spent inside an office building designing and preparing models for clients.[*citation needed*]

History

[edit]



Orangery at the Palace of Versailles, outside Paris

Main article: History of landscape architecture

For the period before 1800, the history of landscape gardening (later called landscape architecture) is largely that of master planning and garden design for manor houses, palaces and royal properties. An example is the extensive work by André Le Nôtre for King Louis XIV of France on the Gardens of Versailles. The first person to write of *making* a landscape was Joseph Addison in 1712. The term landscape architecture was invented by Gilbert Laing Meason in 1828, and John Claudius Loudon (1783–1843) was instrumental in the adoption of the term landscape architecture by the modern profession. He took up the term from Meason and gave it publicity in his Encyclopedias and in his 1840 book on the *Landscape Gardening and Landscape Architecture of the Late Humphry Repton*.[6]

John Claudius Loudon was an established and influential horticultural journalist and Scottish landscape architect whose writings were instrumental in shaping Victorian taste in gardens, public parks, and architecture.[7] In the *Landscape Gardening and Landscape Architecture of the Late Humphry Repton,* Loudon describes two distinct styles of landscape gardening existing at the beginning of the 19th century: geometric and natural.[6] Loudon wrote that each style reflected a different stage of society. The geometric style was “most striking and pleasing,” displaying wealth and taste in an “early state of society” and in “countries where the general scenery was wild, irregular, and natural, and man, comparatively, uncultivated and unrefined.”[6] The natural style was used in “modern times” and in countries where “society is in a higher state of cultivation," displaying wealth and taste through the sacrifice of profitable lands to make room for such designs.[6]

The prominent English landscape designer Humphry Repton (1752-1818) echoed similar ideas in his work and design ideas. In his writings on the use of delineated spaces (e.g. courtyards, terrace walls, fences), Repton states that while the motive for defense no longer exists, the features are still useful in separating "the gardens, which belong to man, and the forest, or desert, which belongs to the wild denizens."[6] Repton refers to Indigenous peoples as "uncivilized human beings, against whom some decided line of defense was absolutely necessary."[6]

The practice of landscape architecture spread from the Old to the New World. The term "landscape architect" was used as a professional title by Frederick Law Olmsted in the United States in 1863[*citation n* and Andrew Jackson Downing, another early American landscape designer, was editor of *The Horticulturist* magazine (1846–52). In 1841 his first book, *A Treatise on the Theory and Practice of Landscape Gardening, Adapted to North America*, was published to a great success; it was the first book of its kind published in the United States.[8] During the latter 19th century, the term landscape architect began to be used by professional landscapes designers, and was firmly established after Frederick Law Olmsted Jr. and Beatrix Jones (later Farrand) with others founded the American Society of Landscape Architects (ASLA) in 1899. IFLA was founded at Cambridge, England, in 1948 with Sir Geoffrey Jellicoe as its first president, representing 15 countries from Europe and North America. Later, in 1978, IFLA's Headquarters were established in Versailles.[9][10][11]

Fields of activity

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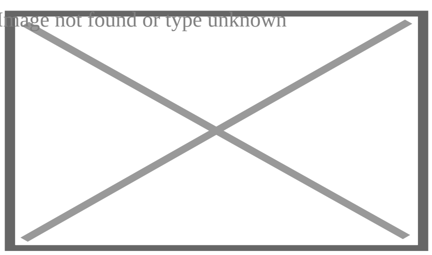
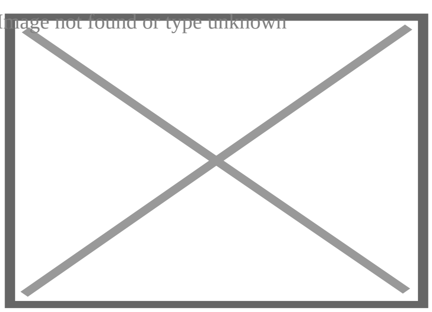


Royal Botanic Gardens, Kew, London, established 1759
The Palm House, Kew, built 1844–1848 by Richard Turner to Decimus Burton's designs



Urban design in city squares. Water feature in London, by Tadao Ando who also works with landscapes and gardens

The variety of the professional tasks that landscape architects collaborate on is very broad, but some examples of project types include:[12]

- Parks of general design and public infrastructure
- Sustainable development
- Stormwater management including rain gardens, green roofs, groundwater recharge, green infrastructure, and constructed wetlands.
- Landscape design for educational function and site design for public institutions and government facilities
- Parks, botanical gardens, arboretums, greenways, and nature preserves
- Recreation facilities, such as playgrounds, golf courses, theme parks and sports facilities
- Housing areas, industrial parks and commercial developments
- Estate and residence landscape planning and design
- Landscaping and accents on highways, transportation structures, bridges, and transit corridors
- Contributions to urban design, town and city squares, waterfronts, pedestrian schemes
- Natural park, tourist destination, and recreating historical landscapes, and historic garden appraisal and conservation studies
- Reservoirs, dams, power stations, reclamation of extractive industry applications or major industrial projects and mitigation
- Environmental assessment and landscape assessment, planning advice and land management proposals.
- Coastal and offshore developments and mitigation
- Ecological design (any aspect of design that minimizes environmentally destructive impacts by integrating itself with natural processes and sustainability)

Landscape managers use their knowledge of landscape processes to advise on the long-term care and development of the landscape. They often work in forestry, nature conservation and agriculture.[*citation needed*]

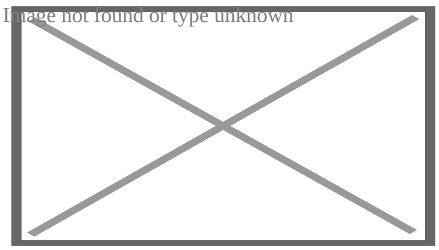
Landscape scientists have specialist skills such as soil science, hydrology, geomorphology or botany that they relate to the practical problems of landscape work. Their projects can range from site surveys to the ecological assessment of broad areas for planning or management purposes. They may also report on the impact of development or the importance of particular species in a given area.[*citation needed*]

Landscape planners are concerned with landscape planning for the location, scenic, ecological and recreational aspects of urban, rural, and coastal land use. Their work is embodied in written statements of policy and strategy, and their remit includes master planning for new developments, landscape evaluations and assessments, and preparing countryside management or policy plans. Some may also apply an additional specialism such as landscape archaeology or law to the process of landscape planning.[*citation needed*]

Green roof (or more specifically, vegetative roof) designers design extensive and intensive roof gardens for stormwater management, evapo-transpirative cooling, sustainable architecture, aesthetics, and habitat creation.[13]

Relation to urban planning

[edit]



The combination of the traditional landscape gardening and the emerging city planning combined gave landscape architecture its unique focus. Frederick Law Olmsted used the term 'landscape architecture' using the word as a profession for the first time when designing the Central Park.

Through the 19th century, urban planning became a focal point and central issue in cities. The combination of the tradition of landscape gardening and the emerging field of urban planning offered landscape architecture an opportunity to serve these needs.[14] In the second half of the century, Frederick Law Olmsted completed a series of parks that continue to have a significant influence on the practices of landscape architecture today. Among these were Central Park in New York City, Prospect Park in Brooklyn, New York and Boston's Emerald Necklace park system. Jens Jensen designed sophisticated and naturalistic urban and regional parks for Chicago, Illinois, and private estates for the Ford family including Fair Lane and Gaukler Point. One of the original eleven founding members of the American Society of Landscape Architects (ASLA), and the only woman, was Beatrix Farrand. She was design consultant for over a dozen universities including: Princeton in Princeton, New Jersey; Yale in New Haven, Connecticut; and the Arnold Arboretum for Harvard in Boston, Massachusetts. Her numerous private estate projects include the landmark Dumbarton Oaks in the Georgetown neighborhood of Washington, D.C.[15] Since that time, other architects – most notably Ruth Havey and Alden Hopkins – changed certain elements of the Farrand design.[*citation n*

Since this period urban planning has developed into a separate independent profession that has incorporated important contributions from other fields such as civil engineering, architecture and public administration. Urban Planners are qualified to perform tasks independent of landscape architects, and in general, the curriculum of landscape architecture programs do not prepare students to become urban planners.[16]

Landscape architecture continues to develop as a design discipline and to respond to the various movements in architecture and design throughout the 20th and 21st centuries. Thomas Church was a mid-century landscape architect significant in the profession. Roberto Burle Marx in Brazil combined the International style and native Brazilian plants and culture for a new aesthetic. Innovation continues today solving challenging problems with contemporary design solutions for master planning, landscapes, and gardens.[*citation needed*]

Ian McHarg was known for introducing environmental concerns in landscape architecture.[17][18] He popularized a system of analyzing the layers of a site in order to compile a complete understanding of the qualitative attributes of a place. This system became the foundation of today's

Geographic Information Systems (GIS). McHarg would give every qualitative aspect of the site a layer, such as the history, hydrology, topography, vegetation, etc. GIS software is ubiquitously used in the landscape architecture profession today to analyze materials in and on the Earth's surface and is similarly used by urban planners, geographers, forestry and natural resources professionals, etc.[*citation needed*]

European nations enabled the widespread circulation of urban planning strategies by transferring landscaping ideas and practices to overseas colonies. The green belt was a popular landscape practice exported by Britain onto colonial territories such as Haifa (1918-1948).[19] Spatial mechanisms like the green belt, implemented through the Haifa Bay Plan and the British "Grand Model," were used to enforce political control and civic order and extend western ideas of progress and development.[19] The Greater London Regional Planning Committee accepted the green belt concept which formed the basis of the 1938 Green Belt Act. The planning prototype demarcated open spaces, distinguished between city and countryside, limited urban growth, and created zoning divisions.[19] It was used extensively in the British colonies to facilitate British rule through the organized division of landscape and populations. [19]

Relation to Indigenous practices

[edit]

Indigenous land management practices create constantly changing landscapes through the use of vegetation and natural systems, contrasting with western epistemologies of the discipline that separate ornament from function.[20] The discipline of landscape architecture favors western designs made from structured materials and geometric forms.[20] Landscape architecture history books tend to include projects that contain constructed architectural elements that persist over time, excluding many Indigenous landscape-based designs.[20]

Landscape architecture textbooks often place Indigenous peoples as a prefix to the official start of the discipline. The widely read landscape history text *The Landscape of Man* (1964) offers a global history of the designed landscape from past to present, featuring African and other Indigenous peoples in its discussions of Paleolithic man between 500,000 and 8,000 BCE in relation to human migration.[20] Indigenous land-management practices are described as archaeological rather than a part of contemporary practice. *Gardens in Time* (1980) also places Indigenous practice as prehistory at the beginning of the landscape architecture timeline. Authors John and Ray Oldham describe Aborigines of Australia as “survivors of an ancient way of life” who provide an opportunity to examine western Australia as a “meeting place of a prehistoric man.”[20]

In the late 18th century, the landscapes created by aboriginal land and fire management practices appealed to English settlers in Australia.[20] Journals from the period of early white settlement note the landscape resembling parks and popular designs in English landscape gardens of the same period.[20] In England, these designs were considered sophisticated and celebrated for the intentional sacrifice of usable land. In Australia, the park-like condition was used to justify British control, citing its emptiness and lack of productive use as a basis for the dispossession of Aboriginal people. [20]

Education

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Landscape Architects are generally required to have university or graduate education from an accredited landscape architecture degree program, which can vary in length and degree title. They learn how to create projects from scratch, such as residential or commercial planting and designing outdoor living spaces[21] they are willing to work with others to get a better outcome for the customers when doing a project; they will have to learn the basics of how to create a project on a manner of time and will require to get your license in a certain state to be allowed to work; students of Landscape Architects will learn how to interact with clients and will learn how to explain a design from scratch when giving the final project.[22]

Landscape architecture has been taught in the University of Manchester since the 1950s. The course in the Manchester School of Architecture enables students to gain various bachelor's and master's degrees, including MLPM(Hons) which is accredited by the Landscape Institute and by the Royal Town Planning Institute.[23]

Profession

[edit]
Main article: Landscape architect

In many countries, a professional institute, comprising members of the professional community, exists in order to protect the standing of the profession and promote its interests, and sometimes also regulate the practice of landscape architecture. The standard and strength of legal regulations governing landscape architecture practice varies from nation to nation, with some requiring licensure in order to practice; and some having little or no regulation. In Europe, North America, parts of South America, Australia, India, and New Zealand, landscape architecture is a regulated profession.[24]

Argentina

[edit]

Since 1889, with the arrival of the French architect and urbanist landscaper Carlos Thays, recommended to recreate the National Capital's parks and public gardens, it was consolidated an apprentice and training program in landscaping that eventually became a regulated profession, currently the leading academic institution is the UBA University of Buenos Aires*"UBA Facultad de Arquitectura, Diseño y Urbanismo"* (Faculty of Architecture, Design and Urbanism) offering a Bacherlor's degree in Urban Landscaping Design and Planning, the profession itself is regulated by the National Ministry of Urban Planning of Argentina and the Institute of the Buenos Aires Botanical Garden.[*citation needed*]

Australia

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The Australian Institute of Landscape Architects (AILA) provides accreditation of university degrees and non-statutory professional registration for landscape architects. Once recognized by AILA, landscape architects use the title 'Registered Landscape Architect' across the six states and territories within Australia.[citation needed]

AILA's system of professional recognition is a national system overseen by the AILA National Office in Canberra. To apply for AILA Registration, an applicant usually needs to satisfy a number of pre-requisites, including university qualification, a minimum number years of practice and a record of professional experience.[25]

Landscape Architecture within Australia covers a broad spectrum of planning, design, management, and research. From specialist design services for government and private sector developments through to specialist professional advice as an expert witness.[citation needed]

Canada

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In Canada, landscape architecture, like law and medicine, is a self-regulating profession pursuant to provincial statute. For example, Ontario's profession is governed by the Ontario Association of Landscape Architects pursuant to the *Ontario Association of Landscape Architects Act*. Landscape architects in Ontario, British Columbia, and Alberta must complete the specified components of L.A.R.E (Landscape Architecture Registration Examination) as a prerequisite to full professional standing.

Provincial regulatory bodies are members of a national organization, the Canadian Society of Landscape Architects / L'Association des Architectes Paysagistes du Canada (CSLA-AAPC), and individual membership in the CSLA-AAPC is obtained through joining one of the provincial or territorial components.[26]

Indonesia

[edit]

ISLA (Indonesia Society of Landscape Architects) is the Indonesian society for professional landscape architects formed on 4 February 1978 and is a member of IFLA APR and IFLA World. The main aim is to increase the dignity of the professional members of landscape architects by increasing their activity role in community service, national and international development. The management of IALI consists of National Administrators who are supported by 20 Regional Administrators (Provincial level) and 3 Branch Managers at city level throughout Indonesia.[*citation neede*

Landscape architecture education in Indonesia was held in 18 universities, which graduated D3, Bachelor and Magister graduates. The landscape architecture education incorporate in Association of Indonesian Landscape Architecture Education.[*citation needed*]

Italy

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AIAPP (Associazione Italiana Architettura del Paesaggio) is the Italian association of professional landscape architects formed in 1950 and is a member of IFLA and IFLA Europe (formerly known as EFLA). AIAPP is in the process of contesting this new law which has given the Architects' Association the new title of Architects, Landscape Architects, Planners and Conservationists whether or not they have had any training or experience in any of these fields other than Architecture. In Italy, there are several different professions involved in landscape architecture:

- Architects
- Landscape designers
- Doctor landscape agronomists and Doctor landscape foresters, often called Landscape agronomists.
- Agrarian Experts and Graduated Agrarian experts.

New Zealand

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The New Zealand Institute of Landscape Architects (NZILA) is the professional body for Landscape Architects in NZ.[27]

In April 2013, NZILA jointly with AILA, hosted the 50th International Federation of Landscape Architects (IFLA) World Congress in Auckland, New Zealand. The World Congress is an international conference where Landscape Architects from all around the globe meet to share ideas around a particular topic.[citation needed]

Within NZ, Members of NZILA when they achieve their professional standing, can use the title Registered Landscape Architect NZILA.[citation needed]

NZILA provides an education policy and an accreditation process to review education programme providers; currently there are three accredited undergraduate Landscape Architecture programmes in New Zealand. Lincoln University also has an accredited masters programme in landscape architecture.[citation needed]

Norway

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Landscape architecture in Norway was established in 1919 at the Norwegian University of Life Sciences (NMBU) at Ås. The Norwegian School of Landscape Architecture at the Faculty of Landscape and Society is responsible for Europe's oldest landscape architecture education on an academic level. The departments areas include design and design of cities and places, garden art history, landscape engineering, greenery, zone planning, site development, place making and place keeping.[citation needed]

South Africa

[edit]

In May 1962, Joane Pim, Ann Sutton, Peter Leutscher and Roelf Botha (considered the forefathers of the profession in South Africa) established the Institute for Landscape Architects, now known as the Institute for Landscape Architecture in South Africa (ILASA).[28] ILASA is a voluntary organisation registered with the South African Council for the Landscape Architectural Profession (SACLAP).[29] It consists of three regional bodies, namely, Gauteng, KwaZula-Natal and the Western Cape. ILASA's mission is to advance the profession of landscape architecture and uphold high standards of professional service to its members, and to represent the profession of landscape architecture in any matter which may affect the interests of the members of the institute. ILASA holds the country's membership with The International Federation of Landscape Architects (IFLA).[30]

In South Africa, the profession is regulated by SACLAP, established as a statutory council in terms of Section 2 of the South African Council for the Landscape Architectural Profession Act – Act 45 of 2000. The Council evolved out of the Board of Control for Landscape Architects (BOCLASA), which functioned under the Council of Architects in terms of The Architectural Act, Act 73 of 1970. SACLAP's mission is to establish, direct, sustain and ensure a high level of professional responsibilities and ethical conduct within the art and science of landscape architecture with honesty, dignity and integrity in the broad interest of public health, safety and welfare of the community.[citation needed]

After completion of an accredited under-graduate and/or post-graduate qualification in landscape architecture at either the University of Cape Town or the University of Pretoria, or landscape technology at the Cape Peninsula University of Technology, professional registration is attained via a mandatory mentored candidacy period (minimum of two years) and sitting of the professional registration exam. After successfully completing the exam, the individual is entitled to the status of Professional Landscape Architect or Professional Landscape Technologist.[citation needed]

Sweden

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Architects Sweden, Sveriges Arkitekter, is the collective trade union and professional organisation for all architects, including landscape architects, in Sweden. The professional body is a member of IFLA (International Federation of Landscape Architects) as well as IFLA Europe.

As a landscape architect, anyone can become a member of Architects Sweden if they have a national or international university degree that is approved by the association. If the degree is from within the European Union, Architects Sweden approves Landscape architect educations listed by IFLA Europe. For educations outside the EU, the association makes an assessment on a statement from the Swedish Council for Higher Education (UHR).

United Kingdom

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The UK's professional body is the Landscape Institute (LI). It is a chartered body that accredits landscape professionals and university courses. At present there are fifteen accredited programmes in the UK. Membership of the LI is available to students, academics and professionals, and there are over 3,000 professionally qualified members.[citation needed]

The Institute provides services to assist members including support and promotion of the work of landscape architects; information and guidance to the public and industry about the specific expertise offered by those in the profession; and training and educational advice to students and professionals looking to build upon their experience.[citation needed]

In 2008, the LI launched a major recruitment drive entitled "I want to be a Landscape Architect" to encourage the study of Landscape Architecture. The campaign aimed to raise the profile of landscape architecture and highlight its valuable role in building sustainable communities and fighting climate change.[31]

As of July 2018, the "I want to be a Landscape Architect" initiative was replaced by a brand new careers campaign entitled *#ChooseLandscape*, which aims to raise awareness of landscape as a profession; improve and increase access to landscape education; and inspire young people to choose landscape as a career.[32] This new campaign includes other landscape-related professions such as landscape management, landscape planning, landscape science and urban design.[33]

United States

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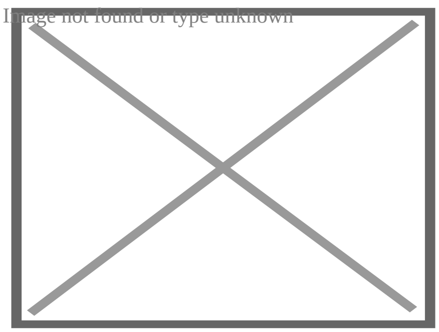

The National Mall in Washington, D.C. includes many examples of landscape architecture based on historical memorials and monuments.

In the United States, landscape architecture is regulated by individual state governments. For a landscape architect, obtaining licensure requires advanced education and work experience, plus passage of the national examination called the Landscape Architect Registration Examination (L.A.R.E.). Licensing is overseen at the national level by the Council of Landscape Architectural Registration Boards (CLARB). Several states require passage of a state exam as well.

Landscape architecture has been identified as an above-average growth profession by the US Bureau of Labor Statistics and was listed in *U.S. News & World Report*'s list of Best Jobs to Have in 2006, 2007, 2008, 2009 and 2010.[34] The national trade association for United States landscape architects is the American Society of Landscape Architects. Frederick Law Olmsted, who designed Central Park in New York City, is known as the "father of American landscape architecture".[35]

Examples

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Potager in Dordogne, France

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Potager in Dordogne, France
Japanese garden in ÃƒÆ’Ã†â€™ÃƒÂ¢Ã¢â€šÂ¬Ã‚Â¦ÃƒÆ’Ã¢â‚¬Â¦ÃƒÂ¢Ã¢â€šÂ¬Ã¢â€žÂ¢tsu, Japan

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Japanese garden in ÃƒÆ’Ã†â€™ÃƒÂ¢Ã¢â€šÂ¬Ã‚Â¦ÃƒÆ’Ã¢â‚¬Â¦ÃƒÂ¢Ã¢â€šÂ¬Ã¢â€žÂ¢tsu
, Japan
Classical Chinese garden

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Classical Chinese garden

Topiary in Helsingborg, Sweden

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  Topiary in Helsingborg, Sweden

Asian sculpture garden in Texas, United States

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  Asian sculpture garden in
  Texas, United States

Vigeland sculpture garden in Oslo, Norway

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  Vigeland sculpture garden in
  Oslo, Norway

Roof terrace garden (Ventimiglia, Italy)

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Roof terrace garden (
Ventimiglia, Italy)
Escorial Formal palace garden in Madrid, Spain

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Escorial Formal palace garden
in Madrid, Spain
Mediterranean garden in Alpes-Maritimes, France

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Mediterranean garden in Alpes-
Maritimes, France

Use of steps at Villa la Magia, in Quarrata, Italy

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Use of steps at Villa la Magia, in
Quarrata, Italy

Lurie Garden in Chicago, United States, GGN & Piet Oudolf

- ○

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Lurie Garden in Chicago,
United States, GGN & Piet
Oudolf

High Line (second section) A repurposed area in New York City, United States

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High Line (second section) A
repurposed area in New York
City, United States

Parque Madrid Rio Formal use of water in Madrid, Spain

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  Parque Madrid Rio Formal use
  of water in Madrid, Spain
  Schouwburgplein Urban park in Rotterdam, Netherlands

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  Schouwburgplein Urban park in
  Rotterdam, Netherlands
  911 Memorial Park A memorial park in New York City United States

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  911 Memorial Park A memorial
  park in New York City United
  States

See also

[edit]

- Energy-efficient landscape design
- Environmental graphic design
- Green roof
- Hard landscape materials
- Landscape architecture design competitions
- Landscape detailing
- Landscape painting
- Landscape engineering
- Landscape products
- Landscape urbanism
- List of landscape architects
- List of schools of landscape architecture
- Planting design
- Principles of intelligent urbanism
- Soft landscape materials
- Sustainable landscape architecture
- Topocide
- Urban forestry
- Urban reforestation

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Horticulture and gardening

Gardening

- Allotment
- Arboretum
- Butterfly
- Climate-friendly gardening
- Community
- Forest
- Foodscaping
- French intensive
- Garden
- Garden design
  - computer-aided
- Groundskeeping
- Garden tool
- Green wall
- Guerrilla
- Historic conservation
- History
- Native
- Parterre
- Proplifting
- Raised bed
- Square foot
- Sustainable
- Xeriscaping

Types of gardens

- Alpine
- Ancient Egypt
- Australian
- Back
- Baroque
- Biblical
- Bog
- Botanical
- Bottle
- Butterfly
- Byzantine
- Cactus
- Colonial
- Color
- Communal
    - Garden square
- Community
- Container
- Cottage
- Dutch
- East Asian
    - Chinese
        - Cantonese
    - Japanese
        - Roji
        - Zen
    - Korean
    - Vietnamese
- English
    - Sharawadgi
- Fernery
- Floating
- Flower
- French
    - formal
    - landscape
    - Renaissance
- Front
- German
- Greek
- Greenhouse
- Hanging
- Islamic
- Italian
- Keyhole
- Kitchen
- Knot
- Market
- Mary

Horticulture

- Agriculture
  - Permaculture
  - stock-free
  - sustainable
  - urban
- Arboriculture
- Bonsai
  - Saikei
- Botany
- Companion planting
- Crop
  - most valuable
- Cutting
- Flora
- Floriculture
  - Canada
  - Taiwan
- Hügelkultur
- Fruticulture
- Genetically modified tree
- Hydroculture
- Indigenous
- Intercropping
- Landscape architecture
- Olericulture
- Plant
  - breeding
  - cuttings
  - free-flowering
  - propagation
  - drought tolerance
  - hardiness
- Pomology
- Postharvest physiology
- Roguing
- Tropical
- Urban
  - agriculture
  - horticulture
  - forestry
  - reforestation
- Viticulture
- Monoculture

Organic

- Biodynamic agriculture
- Grafting
- List of organic gardening and farming topics
- Vegan organic agriculture

Plant protection

- Fungicide
- Herbicide
- Index of pesticide articles
- List of fungicides
- List of insecticides
- Pesticide
- Plant disease forecasting
- Pruning
- Weed control
  - Aquamog weed remover

Related articles

- Community orchard
- Features
- Floral design
  - Floristry
  - Ikebana
- Groundskeeping
- Garden centre
- Garden tourism
- List of gardens
- Lists of plants
- Perennial
- Plant collecting
- Turf management

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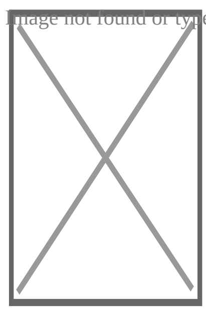
Environmental humanities

Art

- Crop art
- Environmental art
- Environmental sculpture
- Land art
- Landscape painting
- Photography
  - conservation
  - landscape
  - nature
  - wildlife
- Sculpture trail
- Site-specific art
- Sustainable art

Culture

- Cultural ecology
- Cultural landscape
- Ecolinguistics
- Ecological anthropology
- Ecosemiotics
- Environmental anthropology
- Ethnoecology
- Traditional ecological knowledge



Literature

- Ecocomposition
- Ecocriticism
- Ecopoetry
- Geocriticism
- Nature writing
- Outdoor literature

Philosophy

- Aesthetics of nature
- Critical realism
- Deep ecology
- Ecofeminism
- Ecophenomenology
- Ecosophy
- Environmental ethics
- Environmental justice
- Environmental philosophy
- Predation problem
- Social ecology

Religion	◦ Ecotheology ◦ Environmental theology ◦ Religion and environmentalism ◦ Spiritual ecology ◦ Stewardship

Other	◦ Anthrozoology
	◦ Ecomusicology
	◦ Environmental communication
	◦ Environmental education
	    ◦ adult
	    ◦ arts-based
	◦ Environmental history
	◦ Environmental interpretation
	◦ Environmental journalism
	◦ Environmental law
	◦ Outdoor education
	◦ Political representation of nature
	◦ Psychogeography
	◦ Thematic interpretation

Related	◦ Animal studies ◦ Bioethics ◦ Biophilia hypothesis ◦ Do it yourself (ethic) ◦ Natural history (museums) ◦ Popular science ◦ Property theory (common property) ◦ Sexecology ◦ Science, technology and society ◦ science studies ◦ Simple living ◦ Slow food ◦ Spirit of place ◦ Sustainability studies

Applied

- Arts and Crafts movement
- Acoustic ecology
- Biomimicry
- Ecological design
- Ecomuseum
- Educational trail
- Environmental design
- Landscape architecture
  - assessment
  - planning
- Nature center
- New Urbanism
- Sustainable architecture
- Sustainable design
- Sustainable fashion
- Themed walk

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- Journals
- Degrees

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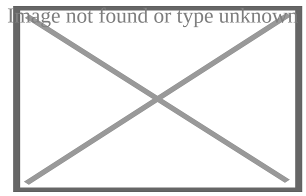
Environmental social science

Fields

- Ecological anthropology
- Ecological economics
- Environmental anthropology
- Environmental crime
- Environmental economics
- Environmental communication
- Environmental history
- Environmental politics
- Environmental psychology
- Environmental sociology
- Human ecology
- Human geography
- Political ecology
- Regional science



Related

- Agroecology
- Anthrozoology
- Behavioral geography
- Community studies
- Demography
- Design
  - ecological
  - environmental
- Ecological humanities
- Economics
  - energy
  - thermo
- Environmental
  - education
  - ethics
  - law
  - science
  - studies
  - justice
  - racism
- Ethnobiology
  - botany
  - ecology
  - zoology
- Forestry
- Industrial ecology
- Integrated geography
- Permaculture
- Political representation of nature
- Rural sociology
- Sexecology
- Science, technology and society
  - science studies
- Sustainability
  - science
  - studies
- Systems ecology
- Urban
  - ecology
  - geography
  - metabolism
  - studies

Applied

- Architecture
  - landscape
  - sustainable
- Ecopsychology
- Engineering
  - ecological
  - environmental
- Green criminology
- Health
  - environmental
  - epidemiology
  - occupational
  - public
- Management
  - environmental
  - fisheries
  - forest
  - natural resource
  - waste
- Planning
  - environmental
  - land use
  - regional
  - spatial
  - urban
- Policy
  - energy
  - environmental

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- Concepts
- Degrees
- Journals
- Research institutes
- Scholars

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Construction

Types	- Home construction - Offshore construction - Underground construction - Tunnel construction
History	- Architecture - Construction - Structural engineering - Timeline of architecture - Water supply and sanitation
Professions	- Architect - Building engineer - Building estimator - Building officials - Chartered Building Surveyor - Civil engineer - Civil estimator - Clerk of works - Project manager - Quantity surveyor - Site manager - Structural engineer - Superintendent
Trades workers (List)	- Banksman - Boilermaker - Bricklayer - Carpenter - Concrete finisher - Construction foreman - Construction worker - Electrician - Glazier - Ironworker - Millwright - Plasterer - Plumber - Roofer - Steel fixer - Welder

Organizations	◦ American Institute of Constructors (AIC) ◦ American Society of Civil Engineers (ASCE) ◦ Asbestos Testing and Consultancy Association (ATAC) ◦ Associated General Contractors of America (AGC) ◦ Association of Plumbing and Heating Contractors (APHC) ◦ Build UK ◦ Construction History Society ◦ Chartered Institution of Civil Engineering Surveyors (CICES) ◦ Chartered Institute of Plumbing and Heating Engineering (CIPHE) ◦ Civil Engineering Contractors Association (CECA) ◦ The Concrete Society ◦ Construction Management Association of America (CMAA) ◦ Construction Specifications Institute (CSI) ◦ FIDIC ◦ Home Builders Federation (HBF) ◦ Lighting Association ◦ National Association of Home Builders (NAHB) ◦ National Association of Women in Construction (NAWIC) ◦ National Fire Protection Association (NFPA) ◦ National Kitchen & Bath Association (NKBA) ◦ National Railroad Construction and Maintenance Association (NRC) ◦ National Tile Contractors Association (NTCA) ◦ Railway Tie Association (RTA) ◦ Royal Institution of Chartered Surveyors (RICS) ◦ Scottish Building Federation (SBF) ◦ Society of Construction Arbitrators
By country	◦ India ◦ Iran ◦ Japan ◦ Romania ◦ Turkey ◦ United Kingdom ◦ United States
Regulation	◦ Building code ◦ Construction law ◦ Site safety ◦ Zoning

Architecture	- Style
	    - List
	- Industrial architecture
	    - British
	- Indigenous architecture
	- Interior architecture
	- Landscape architecture
	- Vernacular architecture

Engineering	- Architectural engineering
	- Building services engineering
	- Civil engineering
	    - Coastal engineering
	    - Construction engineering
	    - Structural engineering
	- Earthquake engineering
	- Environmental engineering
	- Geotechnical engineering

Methods	- List - Earthbag construction - Modern methods of construction - Monocrete construction - Slip forming

- Building material
  - List of building materials
  - Millwork
- Construction bidding
- Construction delay
- Construction equipment theft
- Construction loan
- Construction management
- Construction waste
- Demolition
- Design–build
- Design–bid–build
- DfMA
- Heavy equipment
- Interior design

Other topics

- Lists of buildings and structures
  - List of tallest buildings and structures
- Megaproject
- Megastructure
- Plasterwork
  - Damp
    - Proofing
  - Parge coat
  - Roughcast
    - Harling
- Real estate development
- Stonemasonry
- Sustainability in construction
- Unfinished building
- Urban design
- Urban planning

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Portal:

- Image not found or type unknown iconGardening

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International

- FAST

National	◦ Germany ◦ United States ◦ Japan ◦ Czech Republic ◦ 2 ◦ Spain ◦ Latvia ◦ Israel
Other	◦ NARA ◦ Encyclopedia of Modern Ukraine

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Things To Do in Clark County

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Clark County Historical Museum

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Driving Directions in Clark County

Driving Directions From Field 2 to

Driving Directions From Rock N Block - Turf N Hardscapes to

Driving Directions From Universal Turf Equipment to

Driving Directions From Rhino's Turf Equipment – A part of United Rentals to

Driving Directions From Festival Turf Las Vegas to

Driving Directions From Everything Turf Pros to

Driving Directions From Turf Trimmers Landscaping, Inc. to

Driving Directions From VS Turf Supply to

Driving Directions From Kellogg Zaher Soccer Complex to

Driving Directions From TURFIT LAS VEGAS to

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Reviews for Rock N Block - Turf N Hardscapes

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Terry lewis

(5)

Workers were great, no problem they did what was required, but the representative of your company mislead me on what was to be done, I showed pictures from a competitor landscaper, representative stated he could bet there , , . price, but since it wasn’t in contract, I was left with uncomplicated backyard , working with owner at present, so he’s been outstanding working on this situation, as amount of rock was way off and the owner did increase the amount substantially to finish the front yard. another landscaper under contract to finish the backyard. Would like to add a comment the manger/owner of Las Vegas yard n block stands behind his words and helped me tremendously on finishing up the backyard,

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Josh Bodell

(5)

Eric and team did an amazing job. They worked with me for months while I got HOA approval for the project. Once they began working they were great, going over everything in detail and making sure things were perfect. This project included wall repair, stucco and paint repair, paver and turf installation. Extremely satisfied with this experience.

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Shana Shapiro

(5)

Chris, the design consultant, Dave the production manager, along with their install team Opulent were affordable, upfront with costs, efficient and professional. Attached are some before and after pictures. Highly recommend their services.

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Dawna OgleYohe

(5)

My initial contact was with Ray, whom did an excellent job giving me an estimate on what I wanted done in my small yard and walkway., the guys that came out and did the work were superior. They did an excellent job. I’m very pleased with this company. I will highly recommend them to family and friends, and I will be using them in the near future for other little projects.

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About Rock N Block - Turf N Hardscapes

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Things To Do in Clark County

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Clark County Historical Museum

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Driving Directions From Ugarte Landscapes & Irrigation Repair to

Driving Directions From New horizon landscapes to

Driving Directions From Custom Touch Landscape to

Driving Directions From A and L Desert Landscapes Tree Company to

Driving Directions From Paradise Landscaping Las Vegas to

Driving Directions From Las Vegas Backyards to

Driving Directions From Delfino Maintenance & Landscaping Inc. to

Driving Directions From Rock N Block - Turf N Hardscapes to

Driving Directions From Las Vegas Tree & Landscaping to

Driving Directions From Living Water Lawn & Garden to

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Driving Directions From Clark County Historical Museum to

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Reviews for Rock N Block - Turf N Hardscapes

Image not found or type unknown

D. Lopez

(5)

We recently had a very positive experience with Rock N Block for our fence replacement. The entire process went smoothly and exceeded our expectations. Harvey and his team were incredibly professional and communicative throughout the project providing much-needed assurance and peace of mind. The crew was punctual and maintained a diligent and respectful attitude that made the experience pleasant. The crew finished the project ahead of schedule, and the quality of their work is impressive; our new wall looks great! We recommend Rock N Block for any fencing needs and look forward to working with them again. Thank you, Harvey and crew, for a job well done!

Image not found or type unknown

Terry lewis

(5)

Workers were great, no problem they did what was required, but the representative of your company mislead me on what was to be done, I showed pictures from a competitor landscaper, representative stated he could bet there , , . price, but since it wasn’t in contract, I was left with uncomplicated backyard , working with owner at present, so he’s been outstanding working on this situation, as amount of rock was way off and the owner did increase the amount substantially to finish the front yard. another landscaper under contract to finish the backyard. Would like to add a comment the manger/owner of Las Vegas yard n block stands behind his words and helped me tremendously on finishing up the backyard,

Image not found or type unknown

Dawna OgleYohe

(5)

My initial contact was with Ray, whom did an excellent job giving me an estimate on what I wanted done in my small yard and walkway., the guys that came out and did the work were superior. They did an excellent job. I’m very pleased with this company. I will highly recommend them to family and friends, and I will be using them in the near future for other little projects.

Image not found or type unknown

Shana Shapiro

(5)

Chris, the design consultant, Dave the production manager, along with their install team Opulent were affordable, upfront with costs, efficient and professional. Attached are some before and after pictures. Highly recommend their services.

Image not found or type unknown

Josh Bodell

(5)

Eric and team did an amazing job. They worked with me for months while I got HOA approval for the project. Once they began working they were great, going over everything in detail and making sure things were perfect. This project included wall repair, stucco and paint repair, paver and turf installation. Extremely satisfied with this experience.

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Frequently Asked Questions

What makes Las Vegas landscaping different from other regions?

Las Vegas landscaping is shaped by the Mojave Desert’s extreme climate, with scorching summer heat and minimal rainfall. Traditional lawns demand high water usage, so residents often use xeriscaping techniques that require little irrigation. Designers focus on selecting native or desert-adapted plants—such as succulents, cacti, and ornamental grasses—and pairing them with gravel, boulders, and rock mulch. This approach not only conserves water but also cuts down on labor-intensive maintenance. Additionally, many yards incorporate shade structures, drip irrigation systems, and nighttime lighting to boost usability after sunset. Together, these elements create low-water, visually appealing outdoor spaces that celebrate Las Vegas' desert character.

In which locations does Rock N Block operate?

They operate in Las Vegas, NV; San Diego, CA; Denver, CO; and Utah.

Which outdoor features can a Las Vegas landscaping designer add to my yard?

A skilled designer can incorporate a variety of features that suit desert living. Paver patios or stamped concrete decks handle intense heat and offer comfortable gathering spots. Shade structures, like pergolas or sail canopies, keep daytime temperatures more bearable. Fire pits and seating walls turn cool evenings into social retreats. Decorative rock beds highlight succulents or cacti, adding texture and a modern edge. Small water features—like bubblers or pondless fountains—introduce soothing sounds while reusing water. Low-voltage lighting extends outdoor enjoyment after sunset. The designer tailors each element to your preferences, climate constraints, and overall aesthetic for a balanced, livable yard.

How does Rock N Block ensure quality in artificial grass installation?

They follow a meticulous process, including site preparation, proper base construction, and use of high-quality materials to ensure a durable and aesthetically pleasing result.

What is xeriscaping, and why is it popular in Las Vegas?

Xeriscaping involves designing landscapes that demand minimal water, making it an ideal approach in desert cities like Las Vegas. By favoring native or drought-tolerant plants, gravel-based groundcovers, and drip irrigation, xeriscapes thrive under intense sun with reduced upkeep. This method often replaces large, thirsty lawns, cutting back substantially on irrigation and maintenance costs. Beyond practicality, xeriscapes can be quite striking—mixing textures of succulents, cacti, and rock accents for visual intrigue. Local water authorities frequently offer rebates for removing turf in favor of xeriscape. Ultimately, the popularity arises from combining **water conservation**, aesthetic charm, and simpler routine care, perfectly matching Las Vegas' arid environment.

commercial landscaping Las Vegas

Landscaping Designer Las Vegas

Phone : 888 894 2486

City : Las Vegas

State : Nevada

Zip : 89108

Address : 3267 N Torrey Pines Dr

Google Business Profile

Google Business Website

Company Website : https://rocknblocklandscape.com/artificial-turf/landscaping/

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