BASIC CONCRETE

CONTINUING EDUCATION
PROFESSIONAL DEVELOPMENT COURSE

Technical Learning College

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Concrete Vault

Definition of Confined Spaces Requiring an Entry Permit

A Confined space is:
1. Is large enough or so configured that an employee can bodily enter and perform work.
2. Has limited or restricted means for entry or exit (i.e. tanks, vessels, silos, storage bins, hoppers, vaults, and pits are spaces that may have limited means of entry).
3. Is not designed for continuous employee occupancy.

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TLC
P.O. Box 3060
Chino Valley, AZ 86323

Some States and many employers require the final exam to be proctored.

Technical Learning College's Scope and Function

Welcome to the Program,

Technical Learning College (TLC) offers affordable continuing education for today's working professionals who need to maintain licenses or certifications. TLC holds several different governmental agency approvals for granting of continuing education credit.

TLC's delivery method of continuing education can include traditional types of classroom lectures and distance-based courses or independent study. TLC's distance based or independent study courses are offered in a print - based distance educational format. We will beat any other training competitor's price for the same CEU material or classroom training.

Our courses are designed to be flexible and for you to finish the material at your convenience. Students can also receive course materials through the mail. The CEU course or e-manual will contain all your lessons, activities and instruction to obtain the assignments. All of TLC's CEU courses allow students to submit assignments using e-mail or fax, or by postal mail. (See the course description for more information.)

Students have direct contact with their instructor—primarily by e-mail or telephone. TLC's CEU courses may use such technologies as the World Wide Web, e-mail, CD-ROMs, videotapes and hard copies. (See the course description.) Make sure you have access to the necessary equipment before enrolling; i.e., printer, Microsoft Word and/or Adobe Acrobat Reader. Some courses may require proctored closed-book exams, depending upon your state or employer requirements.

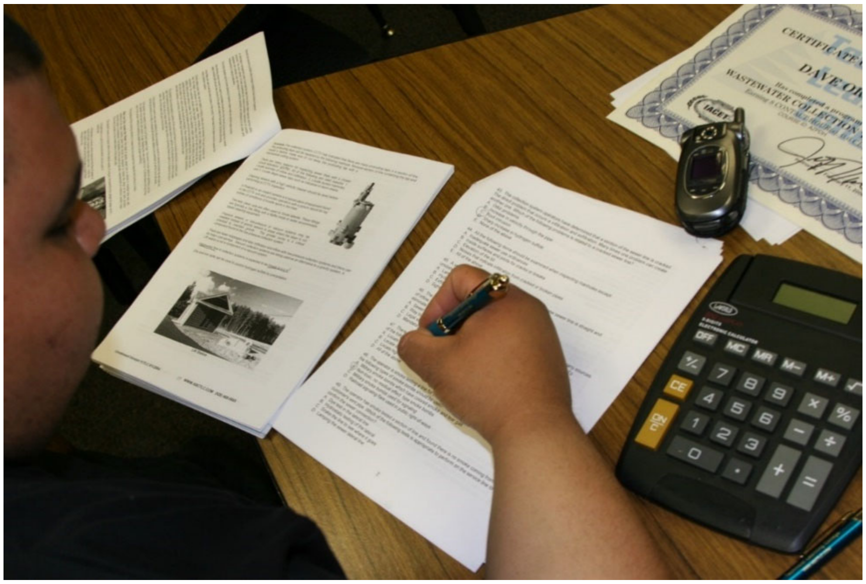
Flexible Learning
At TLC, there are no scheduled online sessions or passwords you need contend with, nor are you required to participate in learning teams or groups designed for the "typical" younger campus based student. You will work at your own pace, completing assignments in time frames that work best for you. TLC's method of flexible individualized instruction is designed to provide each student the guidance and support needed for successful course completion.

Course Structure
TLC's online courses combine the best of online delivery and traditional university textbooks. You can easily find the course syllabus, course content, assignments, and the post-exam (Assignment). This student-friendly course design allows you the most flexibility in choosing when and where you will study.

Classroom of One
TLC offers you the best of both worlds. You learn on your own terms, on your own time, but you are never on your own. Once enrolled, you will be assigned a personal Student Service Representative who works with you on an individualized basis throughout your program of study. Course specific faculty members (S.M.E.) are assigned at the beginning of each course providing the academic support you need to successfully complete each course. Please call or email us for assistance.

Satisfaction Guaranteed

We have many years of experience, dealing with thousands of students. We assure you, our customer satisfaction is second to none. This is one reason we have taught more than 20,000 students.



We welcome you to do the electronic version of the assignment and submit the answer key and registration to us either by fax or e-mail. If you need this assignment graded and a certificate of completion within a 48-hour turn around, prepare to pay an additional rush charge of $50.

Contact Numbers
Fax (928) 468-0675
Email Info@tlch2o.com
Telephone (866) 557-1746

Basic Concrete - Course Description

The target audience for this course is the person who works in the field and has the need or task of working with concrete or cement in their daily operations.

Course Objective: To provide two hours of continuing education training in understanding the fundamentals of cement or concrete products, types, purposes, slump, additives and finishing.

Course Focus
This distance based CEU course will cover concrete basics, workability, concrete slump test, curing, making concrete, and pouring or building with concrete

Target Audience
The primary target audiences for this course are personnel who work in the field or operations /maintenance and work with cement or concrete products. There are no prerequisites, and no other materials are needed for this course.

Course Statement of Need
All operation and maintenance personnel shall be able to describe various cement and/or concrete operations, purposes and finishing.

Prerequisite
Basic math knowledge on at a high school level is recommended for successful completion of this course.

Upon Successful Completion of this Course, You Will Receive
- 0.2 Continuing Education Unit/ two training hours depending on your State.
- A frameable certificate of competition.

General CEU Course Learning Objectives
1. The student will be able to understand and describe what is concrete and its history.
What is Concrete?

2. The student will be able to understand and describe composition of concrete including additives and purposes.

3. The student will be able to understand and describe concrete production and finishing procedures.

Final Examination for Credit
Opportunity to pass the final comprehensive examination is limited to three attempts per course enrollment.

Security and Integrity
All students are required to do their own work. All lesson sheets and final exams are not returned to the student to discourage the sharing of answers. Any fraud or deceit and the student will forfeit all fees and the appropriate agency will be notified.

Grading Criteria
TLC will offer the student either pass/fail or a standard letter grading assignment. If TLC is not notified, you will only receive a pass/fail notice.

Required Texts
The *Basic Concrete* CEU training course will not require any other materials. This course comes complete. No other materials are needed. You may write your answers or type out your own answer key. TLC would prefer that you utilize the answer key found on the TLC website under Assignments and e-mail the answer key to TLC, but it is not required. You may also fax the answer key. Please call us a couple hours later to ensure we received your information. If you should need any assistance, please email all concerns and the final test to: info@tlch2o.com.

Recordkeeping and Reporting Practices
TLC will keep all student records for a minimum of seven years. It is your responsibility to give the completion certificate to the appropriate agencies.

ADA Compliance
TLC will make reasonable accommodations for persons with documented disabilities. Students should notify TLC and their instructors of any special needs.

Course content may vary from this outline to meet the needs of this particular group.

You will have 90 days from receipt of this manual to complete it in order to receive your Continuing Education Units (**CEUs**) or Professional Development Hours (**PDHs**). A score of 70% is necessary to pass this course.

Educational Mission

The educational mission of TLC is:
To provide TLC students with comprehensive and ongoing training in the theory and skills needed for the environmental education field,

To provide TLC students opportunities to apply and understand the theory and skills needed for operator certification,

To provide opportunities for TLC students to learn and practice environmental educational skills with members of the community for the purpose of sharing diverse perspectives and experience,

To provide a forum in which students can exchange experiences and ideas related to environmental education,

To provide a forum for the collection and dissemination of current information related to environmental education, and to maintain an environment that nurtures academic and personal growth.

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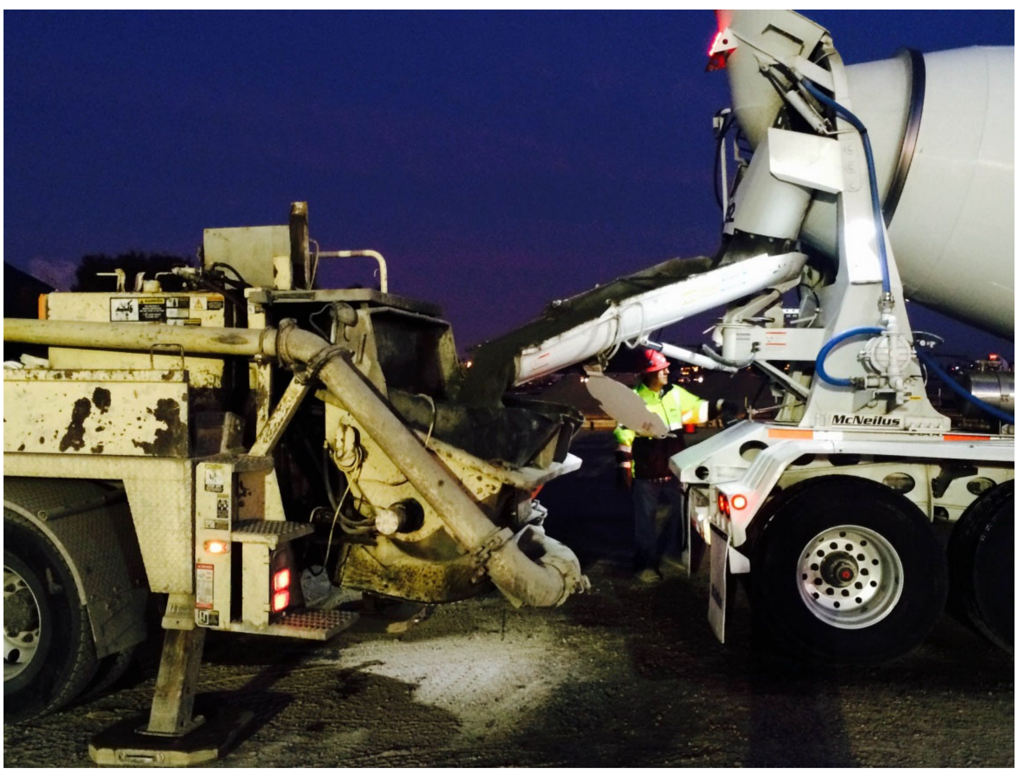

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NAME: ____ **DATE:**____________

This guide does not list every conceivable concrete, excavation, safety or confined space hazard. It is not intended as a legal interpretation of federal or state standards, and should not be used as a substitute for training.

Concrete Introduction

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

Concrete History
Famous concrete structures include the Hoover Dam, the Panama Canal and the Roman Pantheon. The earliest large-scale users of concrete technology were the ancient Romans, and concrete was widely used in the Roman Empire.

Roman Coliseum in Rome

The Coliseum in Rome was built largely of concrete, and the concrete dome of the Pantheon is the world's largest unreinforced concrete dome. After the Roman Empire collapsed, use of concrete became rare until the technology was re-pioneered in the mid-18th century. Today, concrete is the most widely used man-made material (measured by tonnage

Concretus
The word concrete comes from the Latin word "*concretus*" (meaning compact or condensed), the perfect passive participle of "*concrescere*", from "*con-*" (together) and "*crescere*" (to grow).
A deposit of cement was formed after an occurrence of oil shale located adjacent to a bed of limestone burned due to natural causes. These ancient deposits were investigated in the 1960s and 1970s. On a human time-scale, small usages of concrete go back for thousands of years. The ancient Nabatea culture was using materials roughly analogous to concrete at least eight thousand years ago, some structures of which survive to this day.

Ancient Roman City

German archaeologist Heinrich Schliemann found concrete floors, which were made of lime and pebbles, in the royal palace of Tiryns, Greece, which dates roughly to 1400-1200 BC. Lime mortars were used in Greece, Crete, and Cyprus in 800 BC. The Assyrian Jerwan Aqueduct (688 BC) made use of fully waterproof concrete. Concrete was used for construction in many ancient structures.

Roman Period
The Romans used concrete extensively from 300 BC to 476 AD, a span of more than seven hundred years. During the Roman Empire, Roman concrete (or *opus caementicium*) was made from quicklime, pozzolana and an aggregate of pumice. Its widespread use in many Roman structures, a key event in the history of architecture termed the Roman Architectural Revolution, freed Roman construction from the restrictions of stone and brick material and allowed for revolutionary new designs in terms of both structural complexity and dimension.

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

Modern tests show that *opus caementicium* had as much compressive strength as modern Portland-cement concrete (ca. 200 kg/cm^2). However, due to the absence of reinforcement, its tensile strength was far lower than modern reinforced concrete, and its mode of application was also different.

Example of Roman Concrete Design

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.

Roman Aqueduct

The widespread use of concrete in many Roman structures ensured that many survive to the present day. The Baths of Caracalla in Rome are just one example. Many Roman aqueducts and bridges such as the magnificent Pont du Gard have masonry cladding on a concrete core, as does the dome of the Pantheon. After the Roman Empire, the use of burned lime and pozzolana was greatly reduced until the technique was all but forgotten between 500 AD and the 1300s. Between the 1300s until the mid-1700s, the use of cement gradually returned. The *Canal du Midi* was built using concrete in 1670, and there are concrete structures in Finland that date from the 16th century.

Hoover Dam and Bypass

Reinforced concrete was invented in 1849 by Joseph Monier. In 1889 the first concrete reinforced bridge was built, and the first large concrete dams were built in 1936, Hoover Dam and Grand Coulee Dam.

Ancient Concrete Additives
Concrete additives have been used since 6500BC by the Nabataea traders or Bedouins who occupied and controlled a series of oases and developed a small empire in the regions of southern Syria and northern Jordan. They later discovered the advantages of hydraulic lime—that is, cement that hardens underwater—and by 700 BC, they were building kilns to supply mortar for the construction of rubble-wall houses, concrete floors, and underground waterproof cisterns. The cisterns were kept secret and were one of the reasons the Nabataea were able to thrive in the desert. In both Roman and Egyptian times it was re-discovered that adding volcanic ash to the mix allowed it to set underwater. Similarly, the Romans knew that adding horse hair made concrete less liable to crack while it hardened, and adding blood made it more frost-resistant.

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

Modern Concrete Use
Concrete is widely used for making architectural structures, foundations, brick/block walls, pavements, bridges/overpasses, highways, runways, parking structures, dams, pools/reservoirs, pipes, footings for gates, fences and poles and even boats. Concrete is used in large quantities almost everywhere mankind has a need for infrastructure. The amount of concrete used worldwide, ton for ton, is twice that of steel, wood, plastics, and aluminum combined. Concrete's use in the modern world is exceeded only by that of naturally occurring water.

Portland Cement
Portland cement is the basic ingredient of concrete. Concrete is formed when Portland cement creates a paste with water that binds with sand and rock to harden. Cement is manufactured through a closely controlled chemical combination of calcium, silicon, aluminum, iron and other ingredients.

Common materials used to manufacture cement include limestone, shells, and chalk or marl combined with shale, clay, slate, blast furnace slag, silica sand, and iron ore. These ingredients, when heated at high temperatures form a rock-like substance that is ground into the fine powder that we commonly think of as cement.

Joseph Aspdin
Bricklayer Joseph Aspdin of Leeds, England first made Portland cement early in the 19th century by burning powdered limestone and clay in his kitchen stove. With this crude method, he laid the foundation for an industry that annually processes literally mountains of limestone, clay, cement rock, and other materials into a powder so fine it will pass through a sieve capable of holding water.

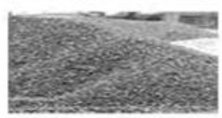
Batching by bucket

High Strength Cement	Coarse sand	Stone	Approximate yield
			
1 Bucket	3 Buckets	3 Buckets	4 ½ Buckets

Batching by wheelbarrow

High Strength Cement	Coarse sand	Stone	Approximate yield
			
2 bags (1 = 50 kg)	3 Wheelbarrows	3 Wheelbarrows	0.3 m^3

Quantities per m^3 of concrete

High Strength Cement	Coarse sand	Stone	Approximate yield
			
6.59 bags (1 = 50 kg)	0.64 m^3	0.64 m^3	1 m^3

Cement plant laboratories check each step in the manufacture of Portland cement by frequent chemical and physical tests. The labs also analyze and test the finished product to ensure that it complies with all industry specifications. The most common way to manufacture Portland cement is through a dry method. The first step is to quarry the principal raw materials, mainly limestone, clay, and other materials. After quarrying the rock is crushed. This involves several stages. The first crushing reduces the rock to a maximum size of about 6 inches. The rock then goes to secondary crushers or hammer mills for reduction to about 3 inches or smaller. The crushed rock is combined with other ingredients such as iron ore or fly ash and ground, mixed, and fed to a cement kiln.

The cement kiln heats all the ingredients to about 2,700 degrees Fahrenheit in huge cylindrical steel rotary kilns lined with special firebrick. Kilns are frequently as much as 12 feet in diameter—large enough to accommodate an automobile and longer in many instances than the height of a 40-story building. The large kilns are mounted with the axis inclined slightly from the horizontal. The finely ground raw material or the slurry is fed into the higher end. At the lower end is a roaring blast of flame, produced by precisely controlled burning of powdered coal, oil, alternative fuels, or gas under forced draft. As the material moves through the kiln, certain elements are driven off in the form of gases. The remaining elements unite to form a new substance called clinker. Clinker comes out of the kiln as grey balls, about the size of marbles.

Clinker is discharged red-hot from the lower end of the kiln and generally is brought down to handling temperature in various types of coolers. The heated air from the coolers is returned to the kilns, a process that saves fuel and increases burning efficiency.

After the clinker is cooled, cement plants grind it and mix it with small amounts of gypsum and limestone. Cement is so fine that 1 pound of cement contains 150 billion grains. The cement is now ready for transport to ready-mix concrete companies to be used in a variety of construction projects.

Although the dry process is the most modern and popular way to manufacture cement, some kilns in the United States use a wet process. The two processes are essentially alike except in the wet process, the raw materials are ground with water before being fed into the kiln.

PROPORTIONS BY WEIGHT TO MAKE 1 CUFT OF CONCRETE

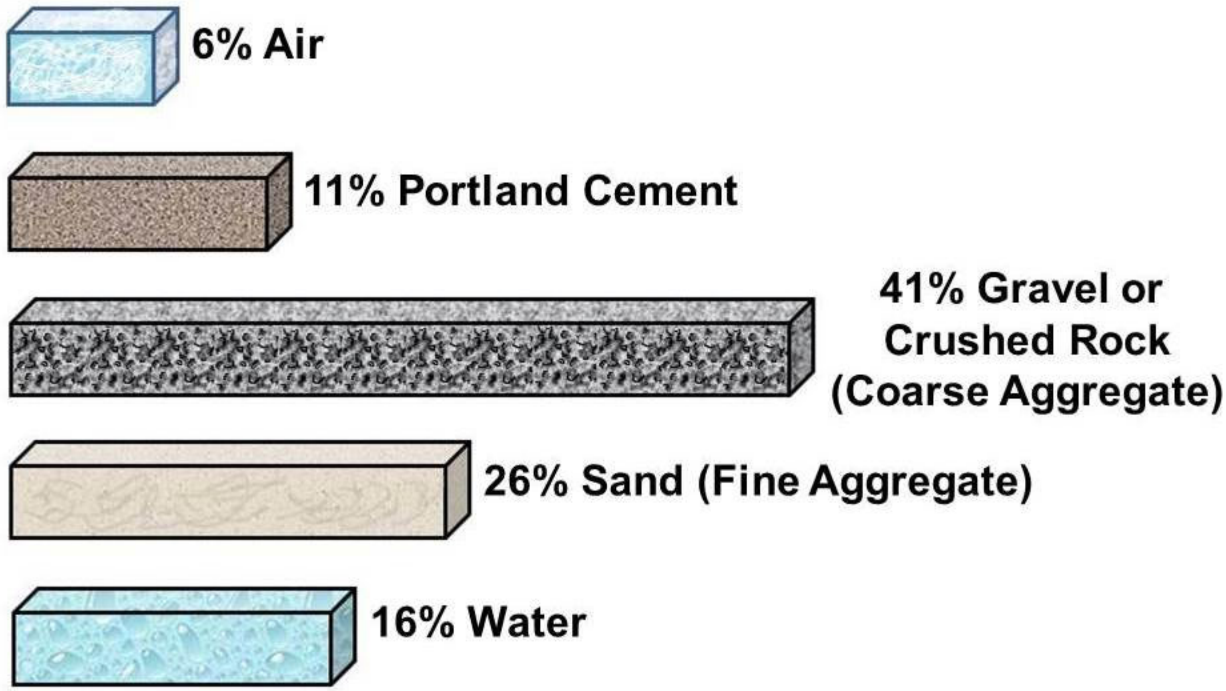
	Air-entrained				Concrete without air			
Maximum-size course aggregate, inch	Cement lbs	Sand lbs	Course aggregate lbs *	Water lbs	Cement lbs	Sand lbs	Coarse aggregate lbs *	Water lbs
3/8	29	53	46	10	29	59	46	11
1/2	27	46	55	10	27	53	55	11
3/4	25	42	65	10	25	47	65	10
1	24	39	70	9	24	45	70	10
1 1/2	23	38	75	9	23	43	75	0

* If crushed stone is used, decrease course aggregate by 3 lbs, and increase sand by 3 lbs

PROPORTIONS BY VOLUME *

	Air-entrained				Concrete without air			
Maximum-size course aggregate, inch	Cement	Sand	Course aggregate	Water	Cement	Sand	Coarse aggregate	Water
3/8	1	2 1/4	1 1/2	1/2	1	2 1/2	1 1/2	1/2
1/2	1	2 1/4	2	1/2	1	2 1/2	2	1/2
3/4	1	2 1/4	2 1/2	1/2	1	2 1/2	2 1/2	1/2
1	1	2 1/4	2 3/4	1/2	1	2 1/2	2 3/4	1/2
1 1/2	1	2 1/4	3	1/2	1	2 1/2	3	1/2

* The combined volume is approximately 2/3 of original bulk.



Composition of Concrete

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

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

"Cement", most commonly Portland cement is associated with the general term "concrete." A range of materials can be used as the cement in concrete. One of the most familiar of these alternative cements is asphalt. Other cementitious materials such as fly ash and slag cement, are sometimes added to Portland cement and become a part of the binder for the aggregate.
Water is then mixed with this dry composite, which produces a semi-liquid that workers can shape (typically by pouring it into a form). The concrete solidifies and hardens through a chemical process called hydration. The water reacts with the cement, which bonds the other components together, creating a robust stone-like material.

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

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

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

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

Water

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

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

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

Reaction:

Cement chemist notation: $C_3S + H \rightarrow C\text{-}S\text{-}H + CH$

Standard notation: $Ca_3SiO_5 + H_2O \rightarrow (CaO)\cdot(SiO_2)\cdot(H_2O)(gel) + Ca(OH)_2$

Balanced: $2Ca_3SiO_5 + 7H_2O \rightarrow 3(CaO)\cdot2(SiO_2)\cdot4(H_2O)(gel) + 3Ca(OH)_2$

Aggregates

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

The presence of aggregate greatly increases the durability of concrete above that of cement, which is a brittle material in its pure state. Thus concrete is a true composite material. Redistribution of aggregates after compaction often creates inhomogeneity due to the influence of vibration. This can lead to strength gradients.

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

Reinforcement

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

Chemical Admixtures
Chemical admixtures are materials in the form of powder or fluids that are added to the concrete to give it certain characteristics not obtainable with plain concrete mixes. In normal use, admixture dosages are less than 5% by mass of cement and are added to the concrete at the time of batching/mixing.

The common types of admixtures are as follows.

- Accelerators speed up the hydration (hardening) of the concrete. Typical materials used are CaCl2, $Ca(NO_3)_2$ and $NaNO_3$. However, use of chlorides may cause corrosion in steel reinforcing and is prohibited in some countries, so that nitrates may be favored. Accelerating admixtures are especially useful for modifying the properties of concrete in cold weather.
- Retarders slow the hydration of concrete and are used in large or difficult pours where partial setting before the pour is complete is undesirable. Typical polyol retarders are sugar, sucrose, sodium gluconate, glucose, citric acid, and tartaric acid.
- Air entrainments add and entrain tiny air bubbles in the concrete, which reduces damage during freeze-thaw cycles, increasing durability. However, entrained air entails a trade off with strength, as each 1% of air may decrease compressive strength 5%. 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.
- Plasticizers increase the workability of plastic or "fresh" concrete, allowing it be placed more easily, with less consolidating effort. A typical plasticizer is lignosulfonate. Plasticizers can be used to reduce the water content of a concrete while maintaining workability and are sometimes called *water-reducers* due to this use. Such treatment improves its strength and durability characteristics. Superplasticizers (also called *high-range water-reducers*) are a class of plasticizers that have fewer deleterious effects and can be used to increase workability more than is practical with traditional plasticizers. Compounds used as superplasticizers include sulfonated naphthalene formaldehyde condensate, sulfonated melamine formaldehyde condensate, acetone formaldehyde condensate and polycarboxylate ethers.
- Pigments can be used to change the color of concrete, for aesthetics.
- Corrosion inhibitors are used to minimize the corrosion of steel and steel bars in concrete.
- Bonding agents are used to create a bond between old and new concrete (typically a type of polymer) with wide temperature tolerance and corrosion resistance.
- Pumping aids improve pumpability, thicken the paste and reduce separation and bleeding.

Sample #	**W**	**X**	**Y**
Slump flow (inch)	18	17	17
Corrected air (%)	6.1	7.1	6.4
HRWR batched (mL)	66	60	45
Wet density (pcl)	12	119	120
Sand/Total Aggregate Ration	0.61	1.54	0.47
Cubic Yard Mix (lbs/yrd^3)			
Cement	752	752	752
Sand	1327	1177	1027
EPS	9.8	9.9	9.9
Coarse Aggregate	850	10	1150
Water	301	301	301
Volume %			
Cement	14.2	14.2	14.2
Sand	30.8	273	23.8
EPS	13.9	13.9	14
Course Aggregate	19.3	22.7	26.1
Water	17.9	17.9	17.9
Design Air	4	4	4
7 days compressive str.	3783	3471	3206
28 days Compressive str	4877	4712	4550
(EPS) Expanded PolyStyrene			
(HRWR) High Range Water Reducer			

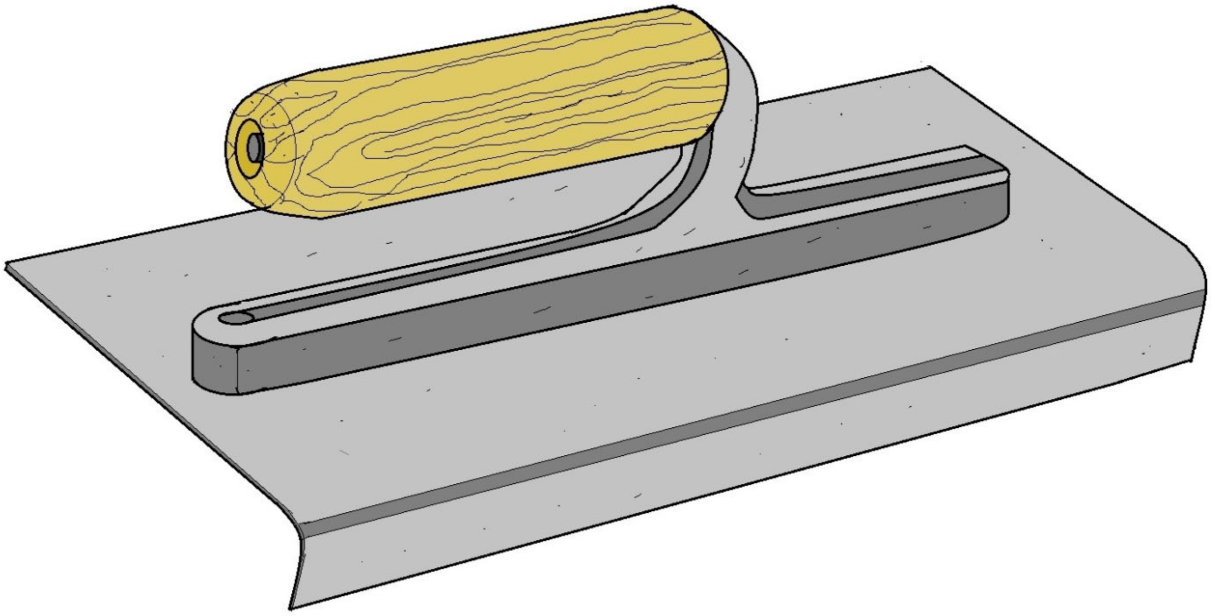
Mineral Admixtures and Blended Cements

Components of Cement Comparison of Chemical and Physical Characteristics					
Property	**Portland Cement**	**Class F Fly Ash**	**Class C Fly Ash**	**Slag Cement**	**Silica Fume**
SiO_2 content (%)	21	52	35	35	85–97
Al_2O_3 content (%)	5	23	18	12	—
Fe_2O_3 content (%)	3	11	6	1	—
CaO content (%)	62	5	21	40	< 1
Specific surface[b] (m^2/kg)	370	420	420	400	15,000–30,000
Specific gravity	3.15	2.38	2.65	2.94	2.22
General use in concrete	Primary binder	Cement replacement	Cement replacement	Cement replacement	Property enhancer
[a]Values shown are approximate: those of a specific material may vary.					
[b]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), or as a replacement for Portland cement (blended cements). Products which incorporate limestone, fly ash, blast furnace slag, and other useful materials with pozzolanic properties into the mix, are being tested and used.

This development is due to cement production being one of the largest producers (at about 5 to 10%) of global greenhouse gas emissions, as well as lowering costs, improving concrete properties, and recycling wastes.

- Fly ash: A by-product of coal-fired electric generating plants, it is used to partially replace Portland cement (by up to 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.
- 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.
- Silica fume: A byproduct 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.
- High reactivity Metakaolin (HRM): Metakaolin produces concrete with strength and durability similar to concrete made with silica fume. While silica fume is usually dark gray or black in color, high-reactivity metakaolin is usually bright white in color, making it the preferred choice for architectural concrete where appearance is important.



CONCRETE EDGER

Concrete Production

Perhaps the greatest driver behind the modern usage of concrete was the third Eddystone Lighthouse in Devon, England. To create this structure, between 1756 and 1793, British engineer John Smeaton pioneered the use of hydraulic lime in concrete, using pebbles and powdered brick as aggregate. A method for producing Portland cement was patented by Joseph Aspdin on 1824.

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

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

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

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

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

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

Mixing Concrete

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

Separate paste mixing has shown that the mixing of cement and water into a paste before combining these materials with aggregates can increase the compressive strength of the resulting concrete. The paste is generally mixed in a *high-speed*, shear-type mixer at a w/cm (water to cement ratio) of 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.

Nano Concrete

Is created by *High-energy mixing* (HEM) of cement, sand and water using a specific consumed power of 30 - 600 watt/kg for a net specific energy consumption of at least 5 kJ/kg of the mix. A plasticizer or a superplasticizer is then added to the activated mixture which can later be mixed with aggregates in a conventional concrete mixer. In the HEM process, sand provides dissipation of energy and increases shear stresses on the surface of cement particles.

The quasi-laminar flow of the mixture characterized with Reynolds number less than 800 is necessary to provide more effective energy absorption. This results in the increased volume of water interacting with cement and acceleration of Calcium Silicate Hydrate (C-S-H) colloid creation.

The initial natural process of cement hydration with formation of colloidal globules about 5 nm in diameter after 3-5 min of HEM spreads out over the entire volume of cement – water matrix. HEM is the "bottom-up" approach in Nanotechnology of concrete. The liquid activated mixture is used by itself for casting small architectural details and decorative items, or foamed (expanded) for lightweight concrete. HEM Nano concrete hardens in low and subzero temperature conditions and possesses an increased volume of gel, which drastically reduces capillarity in solid and porous materials.

Finishing an airport tarmac

Saw cutting expansion joints in a fresh pour.

Workability
Workability is the ability of a fresh (plastic) concrete mix to fill the form/mold properly with the desired work (vibration) and without reducing the concrete's quality. Workability depends on water content, aggregate (shape and size distribution), cementitious content and age (level of hydration) and can be modified by adding chemical admixtures, like superplasticizer.

Raising the water content or adding chemical admixtures increases concrete workability. Excessive water leads to increased bleeding (surface water) and/or segregation of aggregates (when the cement and aggregates start to separate), with the resulting concrete having reduced quality. The use of an aggregate with an undesirable gradation can result in a very harsh mix design with a very low slump, which cannot readily be made more workable by addition of reasonable amounts of water.

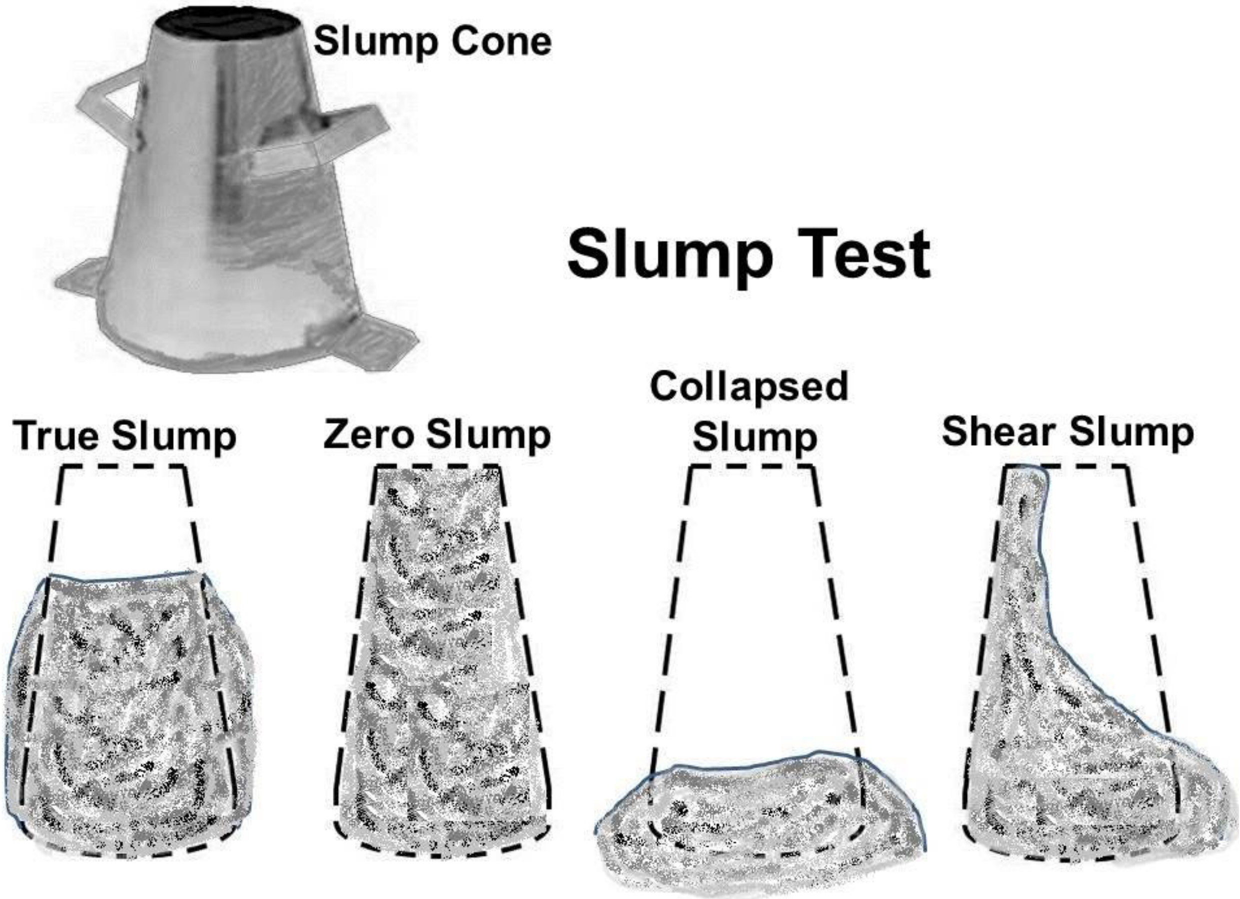
Concrete Slump Test

Workability can be measured by the concrete slump test, a simplistic measure of the plasticity of a fresh batch of concrete following the ASTM C 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 (305 mm). A relatively wet concrete sample may slump as much as eight inches. Workability can also be measured by the flow table test.

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

High-flow concrete, like self-consolidating concrete, is tested by other flow-measuring methods. One of these methods includes placing the cone on the narrow end and observing how the mix flows through the cone while it is gradually lifted. After mixing, concrete is a fluid and can be pumped to the location where needed.


Slump Cone
Slump Test
True Slump
Zero Slump
Collapsed Slump
Shear Slump

A homeowner's broom-finished pour.

Curing

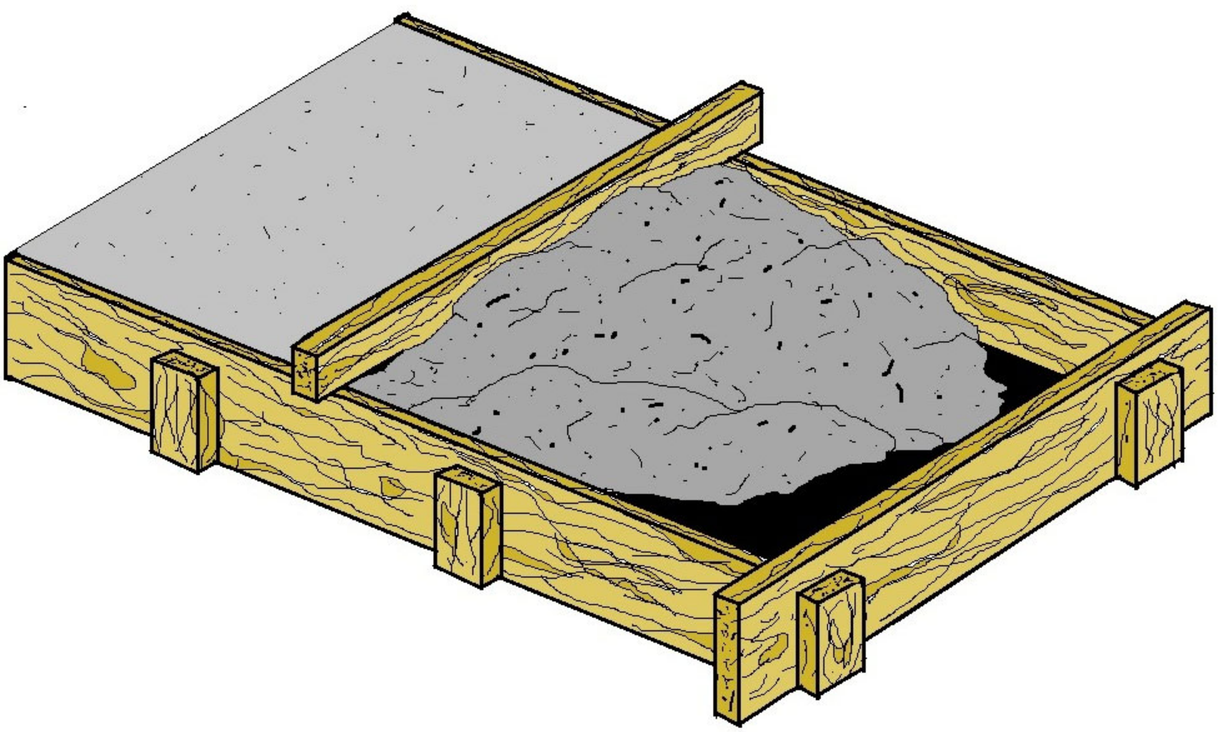
In all but the least critical applications, care must be taken to properly *cure* concrete, to achieve best strength and hardness. This happens after the concrete has been placed. Cement requires a moist, controlled environment to gain strength and harden fully. The cement paste hardens over time, initially setting and becoming rigid though very weak and gaining in strength in the weeks following. In around 4 weeks, typically over 90% of the final strength is reached, though strengthening may continue for decades. The conversion of calcium hydroxide in the concrete into calcium carbonate from absorption of CO_2 over several decades further strengthens the concrete and makes it more resistant to damage. However, this reaction, called carbonation, lowers the pH of the cement pore solution and can cause the reinforcement bars to corrode.

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

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

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

Curing Time
Concrete is typically designed to be used at the strength it reaches after 28 days, but the hydration process continues for years. During the first two weeks of hydration, it is imperative that the concrete be kept wet or moist, particularly when pouring slabs, sidewalks or foundations. There are several methods for finishing concrete including “floating”, troweling, brooming and brushing. Also, ingredients known as admixtures are available and often used in larger commercial projects to alter or enhance various properties, such as air-entrained additives (insulation), accelerants and retardants (to change the rate of hydration), plasticizers (workability) and coloring agents.



LEVELING CEMENT WITH A 2 X 4

Concrete Properties

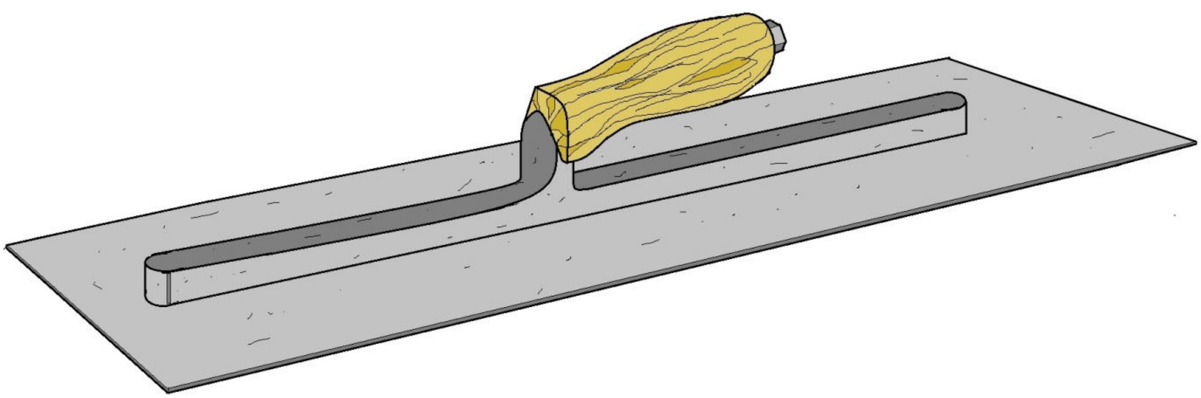
Concrete has relatively high compressive strength, but much lower tensile strength. For this reason it is usually reinforced with materials that are strong in tension (often steel). The elasticity of concrete is relatively constant at low stress levels but starts decreasing at higher stress levels as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

Tests can be performed to ensure that the properties of concrete correspond to specifications for the application. Different mixes of concrete ingredients produce different strengths, which are measured in psi or MPa.

Different strengths of concrete are used for different purposes. Very low-strength (2000 psi or less) concrete may be used when the concrete must be lightweight. Lightweight concrete is often achieved by adding air, foams, or lightweight aggregates, with the side effect that the strength is reduced. For most routine uses, 3000-psi to 4000-psi concrete is often used. 5000-psi concrete is readily commercially available as a more durable, although more expensive, option. 5000-psi concrete is often used for larger civil projects. Strengths above 5000 psi are often used for specific building elements.

For example, the lower floor columns of high-rise concrete buildings may use concrete of 12,000 psi or more, to keep the size of the columns small. Bridges may use long beams of 10,000 psi concrete to lower the number of spans required. Occasionally, other structural needs may require high-strength concrete. If a structure must be very rigid, concrete of very high strength may be specified, even much stronger than is required to bear the service loads. Strengths as high as 19,000 psi have been used commercially for these reasons.

Imperial Strength	Metric Equivalent
2,000 psi	14 MPa
2.500 psi	18 MPa
3,000 psi	20 MPa
3,500 psi	25 MPa
4,000 psi	30 MPa
5,000 psi	35 MPa
6,000 psi	40 MPa
7,000 psi	50 MPa
8,000 psi	55 MPa
10,000 psi	70 MPa
12,000 psi	80 MPa
19,000 psi	130 MPa
36,000 psi	250 MPa



FINISHING TROWEL

Making Concrete

Here is some guidance on how to make concrete. There are four basic ingredients in varying proportions that are required for mixing concrete; Portland cement, sand, aggregate and water. The combined mix is measured in cubic feet; 27 cubic feet is equal to one cubic yard of concrete. Mixing can be done manually in a large plastic tub or wheelbarrow, or in a rotating portable cement mixer.

Portland cement is a fine, white powder consisting of lime, iron, silica and alumina and is available as Types I through V. Type I cement is appropriate for most construction applications and can be purchased in standard bags containing one cubic foot of volume and weighing approximately 95 lbs. The ratio of sand to cement is an important factor in determining the concrete's compressive strength. A ratio of Portland cement to sand at 1:3 will yield a concrete mix with a PSI (pounds per square inch) greater than 3000, sufficient for most minor jobs. Water combined with the cementitious material will form the paste or binder that holds the aggregate in place.

Aggregate or crushed rock, is classified as course, medium and fine, can be used in combination, and typically makes up ¾ of the volume of the concrete. Course aggregate will reduce the volume of cement needed and will not significantly affect the strength of the concrete, but will result in a rough surface finish. The strength properties of the concrete are inversely proportional to the water/cement ratio (by weight) which should be kept below .60. This means the weight of the water should not be more than 60% that of the cement. A higher ratio will produce a more plastic or fluid mix, but one that is likely to be deficient in strength and surface qualities.

Adding water to the mix will initiate the hydration process, a chemical reaction that causes the concrete to harden or "cure". Once poured, compacting is done to eliminate trapped air and vibrating can also be done to ensure uniformity within the mix. Excessive vibration however, will cause segregation, where the heavier aggregates settle near the bottom and the fluid paste rises to the top.

The physical properties of density and strength of concrete are determined, in part, by the proportions of the three key ingredients, water, cement, and aggregate. You have your choice of proportioning ingredients by volume or by weight. Proportioning by volume is less accurate, however due to the time constraints of a class time period this may be the preferred method.

A basic mixture of mortar can be made using the volume proportions of 1 water : 2 cement : 3 sand.

Most of the student activities can be conducted using this basic mixture. Another "old rule of thumb" for mixing concrete is 1 cement : 2 sand : 3 gravel by volume. Mix the dry ingredients and slowly add water until the concrete is workable. This mixture may need to be modified depending on the aggregate used to provide a concrete of the right workability. The mix should not be too stiff or too sloppy. It is difficult to form good test specimens if it is too stiff. If it is too sloppy, water may separate (bleed) from the mixture.

Remember that water is the key ingredient. Too much water results in weak concrete. Too little water results in a concrete that is unworkable.

Suggestions:

1. If predetermined quantities are used, the method used to make concrete is to dry blend solids and then slowly add water (with admixtures, if used).
2. It is usual to dissolve admixtures in the mix water before adding it to the concrete. Superplasticizer is an exception.
3. Forms can be made from many materials. Cylindrical forms can be plastic or paper tubes, pipe insulation, cups, etc. The concrete needs to be easily removed from the forms. Pipe insulation from a hardware store was used for lab trials. This foam-like material was easy to work with and is reusable with the addition of tape. The bottom of the forms can be taped, corked, set on glass plates, etc. Small plastic weighing trays or Dairy Queen banana split dishes can be used as forms for boats or canoes.
4. If compression tests are done, it may be of interest to spread universal indicator over the broken face and note any color changes from inside to outside. You may see a yellowish surface due to carbonation from CO_2 in the atmosphere. The inside may be blue due to calcium hydroxide.
5. To answer the proverbial question, "Is this right?" a slump test may be performed. A slump test involves filling an inverted, bottomless cone with the concrete mixture. A Styrofoam or paper cup with the bottom removed makes a good bottomless cone. Make sure to pack the concrete several times while filling the cone. Carefully remove the cone by lifting it straight upward. Place the cone beside the pile of concrete. The pile should be about 1/2 to 3/4 the height of the cone for a concrete mixture with good workability.

Concrete Block

Concrete block is primarily used as a building material in the construction of walls. It is sometimes called a concrete masonry unit (CMU). A concrete block is one of several precast concrete products used in construction. The term precast refers to the fact that the blocks are formed and hardened before they are brought to the job site. Most concrete blocks have one or more hollow cavities, and their sides may be cast smooth or with a design. In use, concrete blocks are stacked one at a time and held together with fresh concrete mortar to form the desired length and height of the wall.

The first hollow concrete block was designed in 1890 by Harmon S. Palmer in the United States. After 10 years of experimenting, Palmer patented the design in 1900. Palmer's blocks were 8 in (20.3 cm) by 10 in (25.4 cm) by 30 in (76.2 cm), and they were so heavy they had to be lifted into place with a small crane. By 1905, an estimated 1,500 companies were manufacturing concrete blocks in the United States. These early blocks were usually cast by hand, and the average output was about 10 blocks per person per hour. Today, concrete block manufacturing is a highly automated process that can produce up to 2,000 blocks per hour.

Raw Materials

The concrete commonly used to make concrete blocks is a mixture of powdered Portland cement, water, sand, and gravel. This produces a light gray block with a fine surface texture and a high compressive strength. A typical concrete block weighs 38-43 lb (17.2-19.5 kg). In general, the concrete mixture used for blocks has a higher percentage of sand and a lower percentage of gravel and water than the concrete mixtures used for general construction purposes. This produces a very dry, stiff mixture that holds its shape when it is removed from the block mold.

If granulated coal or volcanic cinders are used instead of sand and gravel, the resulting block is commonly called a cinder block. This produces a dark gray block with a medium-to-coarse surface texture, good strength, good sound-deadening properties, and a higher thermal insulating value than a concrete block. A typical cinder block weighs 26-33 lb (11.8-15.0 kg).
Lightweight concrete blocks are made by replacing the sand and gravel with expanded clay, shale, or slate. Expanded clay, shale, and slate are produced by crushing the raw materials and heating them to about 2000°F (1093°C). At this temperature the material bloats, or puffs up, because of the rapid generation of gases caused by the combustion of small quantities of organic material trapped inside.

A typical light-weight block weighs 22-28 lb (10.0-12.7 kg) and is used to build non-load-bearing walls and partitions. Expanded blast furnace slag, as well as natural volcanic materials such as pumice and scoria, are also used to make lightweight blocks.

In addition to the basic components, the concrete mixture used to make blocks may also contain various chemicals, called admixtures, to alter curing time, increase compressive strength, or improve workability. The mixture may have pigments added to give the blocks a uniform color throughout, or the surface of the blocks may be coated with a baked-on glaze to give a decorative effect or to provide protection against chemical attack. The glazes are usually made with a thermosetting resinous binder, silica sand, and color pigments.

Design

The shapes and sizes of most common concrete blocks have been standardized to ensure uniform building construction. The most common block size in the United States is referred to as an 8-by-8-by-16 block, with the nominal measurements of 8 in (20.3 cm) high by 8 in (20.3 cm) deep by 16 in (40.6 cm) wide. This nominal measurement includes room for a bead of mortar, and the block itself actually measures 7.63 in (19.4 cm) high by 7.63 in (19.4 cm) deep by 15.63 in (38.8 cm) wide.

Many progressive block manufacturers offer variations on the basic block to achieve unique visual effects or to provide desirable structural features for specialized applications. For example, one manufacturer offers a block specifically designed to resist water leakage through exterior walls. The block incorporates a water repellent admixture to reduce the concrete's absorption and permeability, a beveled upper edge to shed water away from the horizontal mortar joint, and a series of internal grooves and channels to direct the flow of any crack-induced leakage away from the interior surface.

Another block design, called a split-faced block, includes a rough, stone-like texture on one face of the block instead of a smooth face. This gives the block the architectural appearance of a cut and dressed stone.

Environmental, Safety and Health Issues

The manufacture and use of concrete produce a wide range of environmental and social consequences. Some are harmful, some welcome, and some both, depending on circumstances.

A major component of concrete is cement, which similarly exerts environmental and social effects. The cement industry is one of the three primary producers of carbon dioxide, a major greenhouse gas (the other two being the energy production and transportation industries). As of 2001, the production of Portland cement contributed 7% to global anthropogenic CO_2 emissions, largely due to the sintering of limestone and clay at 1,500 °C (2,730 °F)

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

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

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

Concrete Recycling

Concrete recycling is an increasingly common method of disposing of concrete structures. Concrete debris was once routinely shipped to landfills for disposal, but recycling is increasing due to improved environmental awareness, governmental laws and economic benefits.
Concrete, which must be free of trash, wood, paper and other such materials, is collected from demolition sites and put through a crushing machine, often along with asphalt, bricks and rocks.
Reinforced concrete contains rebar and other metallic reinforcements, which are removed with magnets and recycled elsewhere. The remaining aggregate chunks are sorted by size. Larger chunks may go through the crusher again.

Smaller pieces of concrete are used as gravel for new construction projects. Aggregate base gravel is laid down as the lowest layer in a road, with fresh concrete or asphalt placed over it. Crushed recycled concrete can sometimes be used as the dry aggregate for brand new concrete if it is free of contaminants, though the use of recycled concrete limits strength and is not allowed in many jurisdictions.

Concrete Degradation

Concrete can be damaged by many processes, such as the expansion of corrosion products of the steel reinforcement bars, freezing of trapped water, fire or radiant heat, aggregate expansion, sea water effects, bacterial corrosion, leaching, erosion by fast-flowing water, physical damage and chemical damage (from carbonatation, chlorides, sulfates and distillate water).

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

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

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

Concrete Textures
When one thinks of concrete, the image of a dull, gray concrete wall often comes to mind. With the use of form liner, concrete can be cast and molded into different textures and used for decorative concrete applications. Sound/retaining walls, bridges, office buildings and more serve as the optimal canvases for concrete art.

Building with Concrete
Concrete is one of the most durable building materials. It provides superior fire resistance compared with wooden construction and gains strength over time. Structures made of concrete can have a long service life. Concrete is used more than any other manmade material in the world. More than 55,000 miles (89,000 km) of highways in the United States are paved with this material. Reinforced concrete, pre-stressed concrete and precast concrete are the most widely used types of concrete functional extensions in modern days.

Concrete Roads
Concrete roads are more fuel efficient to drive on, more reflective and last significantly longer than other paving surfaces, yet have a much smaller market share due to many old misconceptions. MIT is lead research in Life Cycle Analysis that is proving the short and long term value of concrete for road surfaces. Modern paving methods and design practices completely change the economics of concrete paving. Oftentimes, a well-designed and placed concrete pavement will be less expensive on initial costs and significantly less expensive over the life cycle.

Energy Efficiency
Energy requirements for transportation of concrete are low because it is produced locally from local resources, typically manufactured within 100 kilometers of the job site. Similarly, relatively little energy is used in producing and combining the raw materials (although large amounts of CO_2 are produced by the chemical reactions in cement manufacture). The overall embodied energy of concrete is therefore lower than for most structural materials other than wood.
Once in place, concrete offers great energy efficiency over the lifetime of a building.

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

Pervious Concrete
Pervious concrete is a mix of specially graded coarse aggregate, cement, water and little-to-no fine aggregates. This concrete is also known as "no-fines" or porous concrete. Mixing the ingredients in a carefully controlled process creates a paste that coats and bonds the aggregate particles. The hardened concrete contains interconnected air voids 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.

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

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

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

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

Earthquake Safety
As discussed above, concrete is very strong in compression, but weak in tension. Larger earthquakes can generate very large shear loads on structures. These shear loads subject the structure to both tensile and compressional loads. Concrete structures without reinforcement, like other unreinforced masonry structures, can fail during severe earthquake shaking. Unreinforced masonry structures constitute one of the largest earthquake risks globally.

Useful Life
Concrete can be viewed as a form of artificial sedimentary rock. As a type of mineral, the compounds of which it is composed are extremely stable. Many concrete structures are built with an expected lifetime of approximately 100 years, but researchers have suggested that adding silica fume could extend the useful life of bridges and other concrete uses to as long as 16,000 years. Coatings are also available to protect concrete from damage, and extend the useful life. Epoxy coatings may be applied only to interior surfaces, though, as they would otherwise trap moisture in the concrete. A self-healing concrete has been developed that can also last longer than conventional concrete.

Hand Mixing Concrete Procedures

How to Mix Concrete in a Wheelbarrow
Small amounts of concrete can be easily mixed in a wheelbarrow with a spade or small shovel.

Most cement bags will have mixture recommendations written on the bags.

Small amounts of concrete can be easily mixed in a wheelbarrow with a spade but larger amounts might require a concrete mixer. Towable concrete mixers, both electrical and mechanical.

In the wheelbarrow or concrete mixer, mix cement, gravel, sand and water. For general purpose concrete, the mix can be 1 part cement, 2 parts sand and 3 parts gravel, usually a 90 pound bag needs 6 quarts of water.

You can make your own concrete mix using 1 part cement, 2 parts sand and 3 parts gravel. Three-quarter-fill the average heavy-duty wheelbarrow, put in 6 spades full of gravel, 4 spades full of sand and 2 spades full of cement (which is a ratio of 1 part cement, 2 parts sand and 3 parts gravel). Mix it all together before adding water.

Next add water: approximately half a standard household bucket more or less. Add a little of the water at a time. Mix with the spade from underneath and fold over. Keep doing this and adding the water until the mix is a uniform consistency.

Tip: when mixing, a smaller spade is easier to work with than a larger one. You can easily make your own concrete mix in a wheelbarrow using 1 part cement, 2 parts sand and 3 parts gravel.

Mix it all together before adding water. A smaller spade or shovel is easier to work with than a bigger one.

Adding Water

Safety Tip: Prolonged contact with fresh concrete will burn your skin. Wear safety goggles, gloves, rubber boots and long sleeves when working with concrete.

Start pouring water in and mixing.
Add a little of the water at a time. Mix with the spade from underneath and fold over. Keep doing this and adding the water until it is a uniform consistency. The wet concrete is now ready to pour.

Two Heavy-Duty Wheelbarrows Can Save the Day
Secure your tools a day ahead of time or at least contact the rental store to reserve them for the pour day to make sure they're at the site when the truck comes. Rent each of these tools:

- Contractor-grade wheelbarrows with leak-free tires. Even on small pours, you'll be in big trouble if your sole wheelbarrow gets a flat tire or a broken handle, so get two! It'll also speed up the pour. A full ready-mix truck at the curb with no way to unload it is expensive. Concrete is heavy. The neighbor's garden-grade petunia hauler will collapse under a load of concrete, and the hard, narrow tires make for tough wheeling in soft ground or gravel.
- Bull float with an extension handle if necessary.
- Concrete broom.
- A groover that cuts control joints 1 in. deep. If the rental store only has groovers for shallow cuts, use it to shape the joints and deepen them with the corner of a trowel or a stiff putty knife.
- Two magnesium hand floats.
- Two edgers.

Top: Pouring the mud in 2 x 4 form. It is good to place steel hog wire or re-bar to reinforce the pour and keep the pad from cracking. Bottom: Using a 2 x 4 to level and tamp the cement. You can actually finish the cement with a board and give a broom finish to top. I suggest an edger tool or you'll have sharp edges. A sharp edge is okay in a farm setting to help wipe of boots.

Using a hand float to smooth out the cement. I suggest allowing the pour to set up in about one hour and start the final finish. This period is dependent on the weather and you can generally tell how the mud is setting up by the amount of water or fat on the top. I like to wait until the excess water is gone but the white or dry cement is not beginning**.**

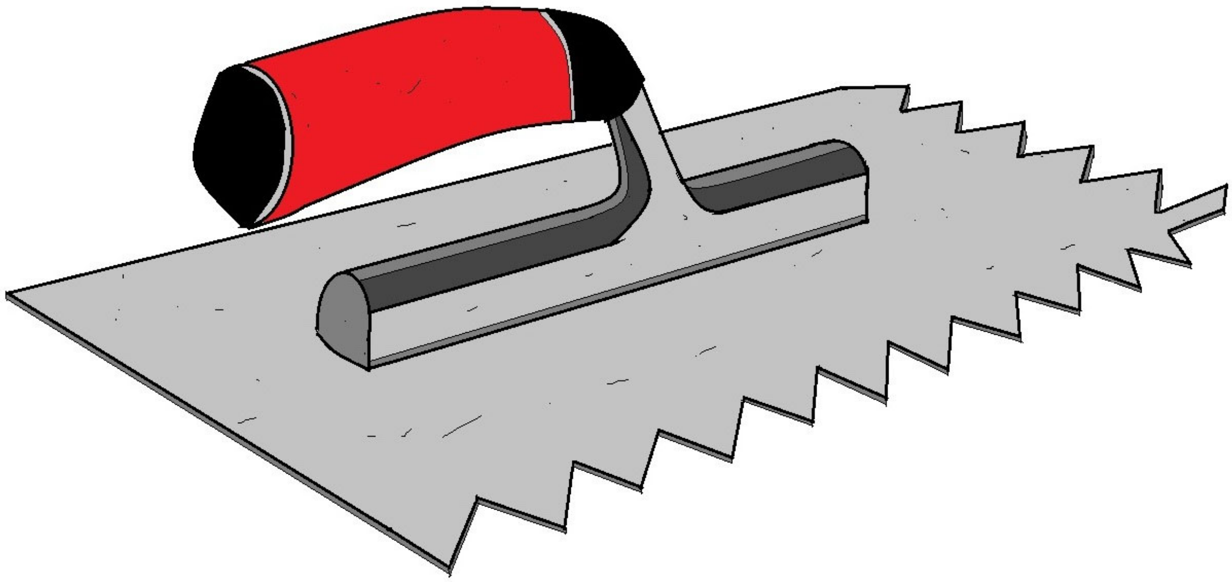
Supplies:

- Sacked Concrete Mix 60, 80 and 90 pound bags are available.
- Pigment, Water Reducer, CHENG Pro-Formula or other all-in-one Admixture (optional).
- Concrete Mixer or shovel (there is a wide range of mixers out there).
- Buckets (You can estimate you'll need 6 quarts of water per 90 pounds of premix, and clean-up water.
- Particle Mask
- Thick Rubber Gloves
- Trowel and Edger

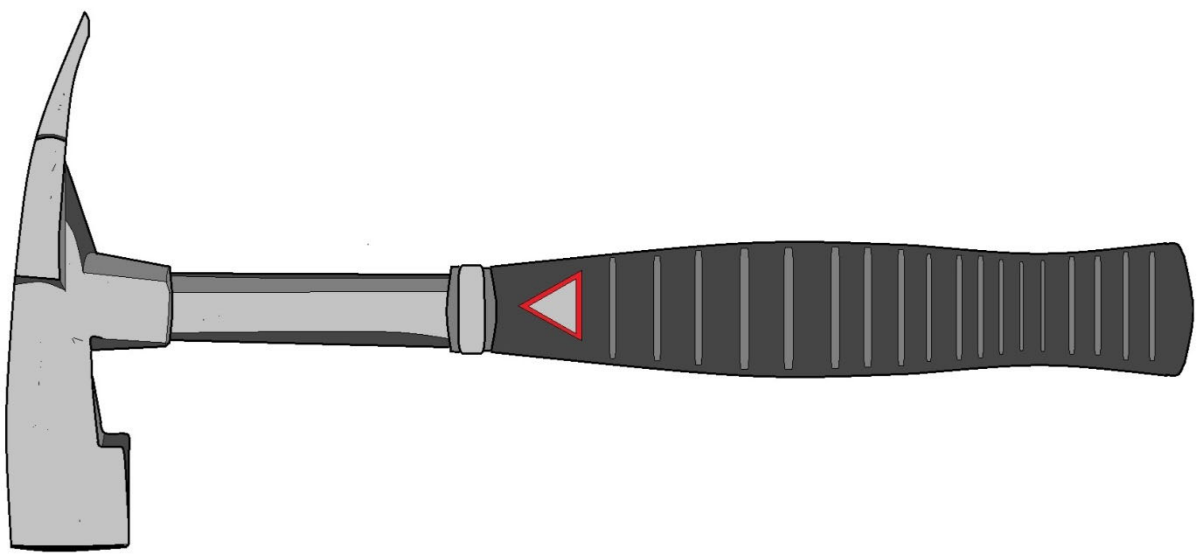
In General:

- Calculate the amount of concrete you'll need using a little bit of math or online volume calculators (don't subtract for knockouts).
- Always mix up more concrete than you think you'll need.
- Don't use sacked concrete that has been exposed to moisture and is hard like a rock.
- Always throw out any big clumps in the mix that won't break up when squeezed in your hand.
- If the mix is getting too stiff, agitating it with vibration will help it become fluid again.

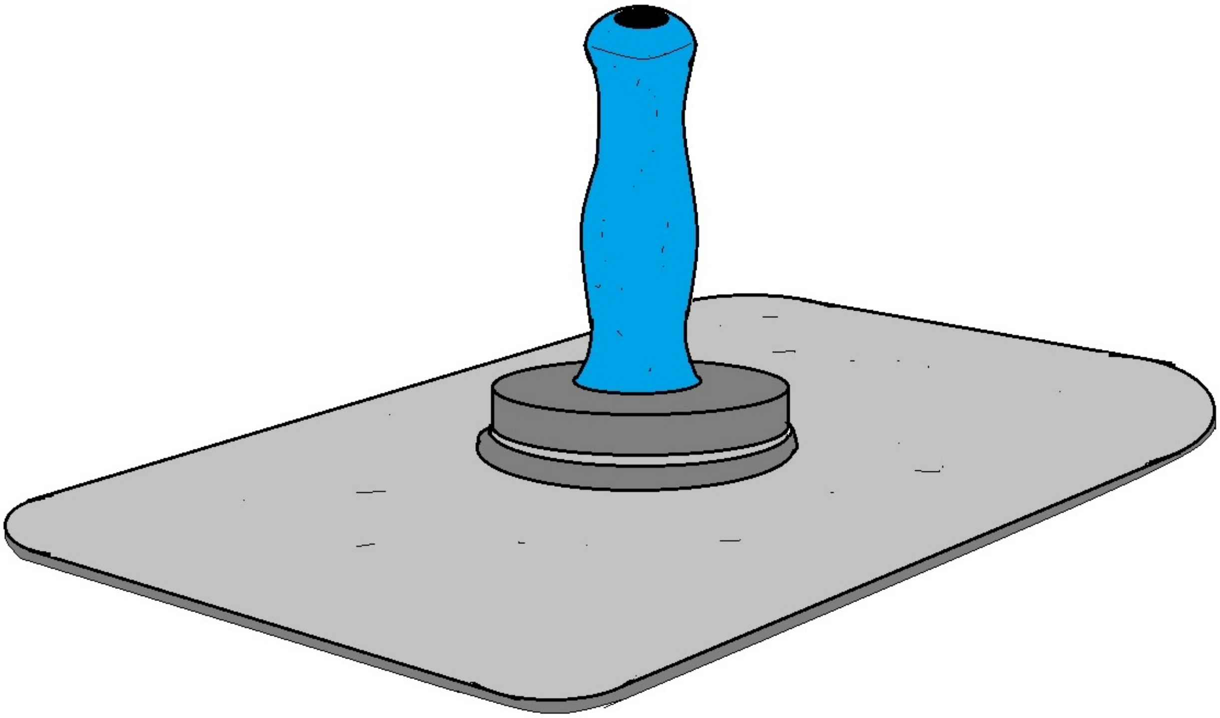
Common Mortar Tools



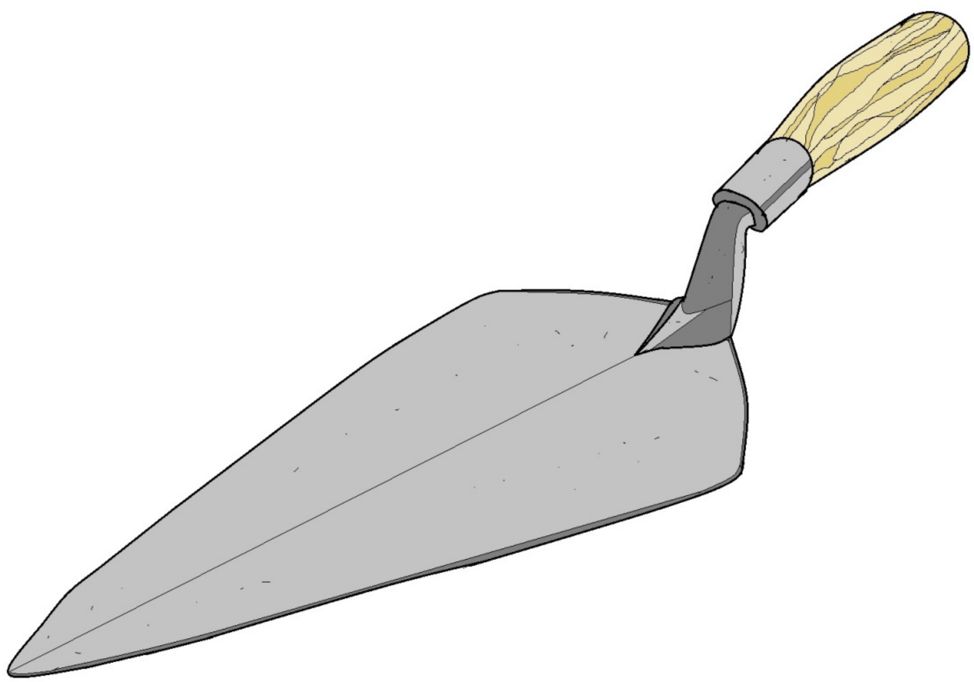
NOTCHED TROWEL



BRICKLAYERS HAMMER



HAWK



MASON'S TROWEL

Concrete Glossary

Accelerators: Admixtures that decrease the setting time by increasing the rate of hydration.

Admixture: A material other than water, aggregates, or cement that is used as an ingredient of concrete or mortar to control setting and early hardening, workability, or to provide additional cementing properties.

Aggregate: Inert solid bodies such as crushed rock, sand, gravel.

Binder: Hardened cement paste.

Bleed: To have water seep to the surface of the cement paste due to settling.

Calcination: Decomposition due to the loss of bound water and carbon dioxide.

Cement: Finely powdered mixtures of inorganic compounds which when combined with water hardens with hydration.

Cement paste: Cement plus water. When the mass has reacted with water and developed strength it is called hardened cement paste.

Clay: Type of soil consisting of very fine particles.

Clinker: The material that emerges from the cement kiln after burning. It is in the form of dark, porous nodules which are ground with a small amount of gypsum to give cement.

Compression: Forces acting inwardly on a body.

Concrete: A hard compact building material formed when a mixture of cement, sand, gravel, and water undergoes hydration.

Cure: To keep concrete moist during initial hardening.

Deformation: The process of changing the dimensions of a structure by applying a force.

Dormancy period: Time period that concrete retains it workability.

Elasticity: The ability of a material to return to its original shape after being stretched.

Forms: Holders in which concrete is placed to harden.

Gypsum: Calcium sulfate dihydrate, $CaSO_4 \cdot 2H_2O$ added to cement to regulate setting.

Hydration: The reaction of cement with water to form a chemical compound.

Kiln: High temperature oven.

Limestone: Mineral rock of calcium carbonate.

Mortar: Cement paste mixed with sand.

Pozzolan cement: Volcanic rock powdered and used in making hydraulic cement.

Porosity: The amount of empty space in concrete.

Portland cement: A cement consisting predominantly of calcium silicates which reacts with water to form a hard mass.

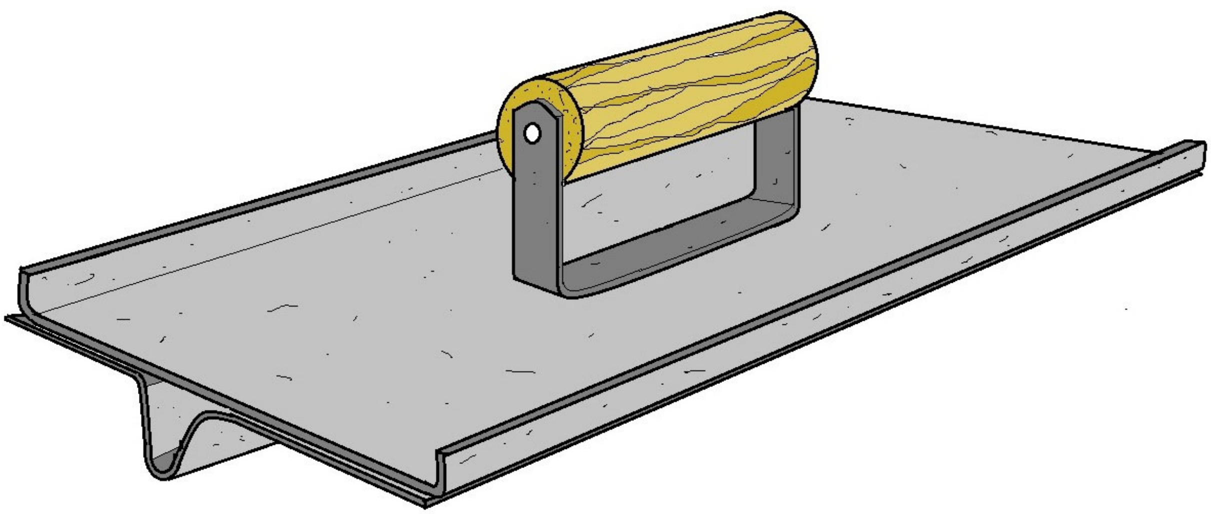
Retardants: Admixtures that increase the setting time by slowing down hydration.

Set: Transformation of cement paste or concrete from a fluid-like consistency to a stiff mass.

Slump test: Test used to determine workability.

Tension: The stress resulting from elongation.

Workability: How easily fresh concrete can be placed and consolidated in forms.



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