Section 2
Construction Materials

Construction Technology Headline

Plastic Pipe and Trenchless Technology Reduce Cost of Rehabilitating Water Mains

An American Water Works Association (AWWA) study estimates that leaks in deteriorated water mains waste 2.45 billion gallons of water annually in the United States. Leaks in individual mains have been found that lose up to 1000 gallons per minute. The average city loses 16 percent of its treated water *before* the water reaches the consumer. Washington, DC losses exceed 50 percent. The primary cause of the problem is corrosion of aging metal piping systems.

One solution to the problem is to replace aging water mains with plastic pipes. Traditionally, new water pipes are put in place by digging a trench, removing old pipe, and laying new pipe in the trench. This is an expensive process. Less expensive processes involve installing pipe using trenchless technology. Replacement technologies include:

- Horizontal drilling—a tunnel is bored horizontally, creating a hole into which new pipe is inserted.
- Slip lining—new pipe is inserted into old pipe.
- Pipe bursting—tool is inserted into and breaks existing pipe. New pipe is inserted.

Trenchless techniques can be completed more quickly than open-trench methods. Streets, driveways, waterways, and existing utilities do not have to be destroyed, moved, and replaced.

Chapter 6
Concrete

Objectives

After studying this chapter, you will be able to:

- Identify at least three different types of Portland cement.
- Describe the aggregate used to make concrete.
- Discuss the purpose of admixtures.
- Describe the reinforcing steel used in concrete.
- Identify four factors that control the quality of concrete.
- Describe the processes involved in working with concrete.
- Calculate the volume of concrete needed for a simple project.
- Discuss the importance of proper curing.
- Describe two tests that are used when working with concrete.

Technical Terms

admixtures
aggregate
air-entrained concrete
compression
compression tests
concrete
consolidation
cubic yard
curing
darbying
edging
floating
form ties
hydration
jointing
Portland cement
puddling sticks
reinforcing bars (rebar)
screeding
slump cone
slump tests
subgrade
tension
troweling

Career Connection

Architecture & Construction

Concrete Finisher

Concrete finishers place and finish concrete. Much of the work involves finishing floors, driveways, and other flat surfaces. In addition to typical finishing processes, concrete finishers may color the surface or apply special aggregate to produce an exposed aggregate surface. Concrete finishers may also fabricate concrete columns, beams, and panels. Finishers also repair damaged areas after forms are removed.

The work can be fast-paced and strenuous. Bending and working in a kneeling position are typical. Work areas are often muddy, dusty, or dirty. Kneepads and water repellent boots are often worn.

Concrete finishers learn the trade through apprenticeship programs, technical schools, or on-the-job training. A high school diploma is often required. High school courses in general science, mathematics, blueprint reading, and mechanical drawing are helpful.

Most work is done outdoors, so weather delays are common. Overtime is often required to make up for weather delays. Overtime is also required because once concrete is poured, it must be finished regardless of the time on the clock.

Job opportunities for concrete finishers are expected to grow for at least the next several years. Most concrete finishers work for specialty contractors. Wages range from approximately $9.00 to $26.00 per hour. Poor weather and slowdowns in construction business can result in lower income.

concrete: Manufactured stone composed of Portland cement, water, and aggregate.

Portland cement: An adhesive that holds the aggregate together to make concrete.

Concrete

Concrete is a building material used in almost every type and size of structure, **Figure 6-1**. In buildings it is used for footings, foundations, and walls. It is used for flat structures of all kinds, like roadways and floors.

Ingredients

Concrete is made of three ingredients: Portland cement, water, and aggregate. Steel reinforcing bars and welded wire fabric are used to strengthen concrete.

Portland cement is made by mixing limestone, clay, and shale. The mixture is burned in a oven at approximately 2700°F (1482°C), resulting in rocklike shapes called clinker. The clinker is pulverized and mixed with a small amount of gypsum to produce Portland cement. There are five types of Portland cement, each designed for specific applications.

- Type I—General purpose. Used when special properties are not required.
- Type II—Moderate sulfate resistance. Used when surrounding soil contains elevated levels of sulfate.
- Type III—High, early strength. Used when it is necessary to speed the curing process.
- Type IV—Low heat. Used in massive concrete structures, such as dams. Type IV cement reduces the internal cracking that might occur as a result of the heat generated during the curing process. Strength develops more slowly when this type of cement is used.

Figure 6-1. Concrete is used in a variety of ways. *(HNTB Engineers; The Manitowoc Co.; Raymond International, Inc.)*

- Type V—Sulfate resistant. Used when concrete will be exposed to severe sulfate conditions, such as those found in some western states.

The **aggregate** consists of fine sand (1/4″ diameter and less) and stones (larger than 1/4″ diameter). The cement paste binds the aggregate together, filling the spaces between particles. A chemical reaction between the water and the Portland cement, called **hydration**, cures (hardens) the concrete.

When mixed with the proper amount of water, Portland cement makes a paste that cures to bond the aggregate together. Tap water is generally acceptable for making concrete. Avoid water containing large amounts of sulfates.

Admixtures

Admixtures are special chemicals added to concrete to change one or more characteristics of the product. Some chemicals make concrete set faster. Other chemicals lengthen the setting time. **Air-entrained concrete** contains an admixture that causes small air bubbles to form in concrete. This concrete is easier to work and resists cracking from freezing and thawing. The letter *A* is added to the type designation (Type I-A) of Portland cement that contains air-entraining chemicals.

aggregate: The sand and gravel in concrete.

hydration: A chemical reaction between water and Portland cement that cures concrete.

admixtures: Chemicals added to concrete to change one or more characteristics of the product.

air-entrained concrete: A type of concrete produced by adding an admixture that causes the tiny bubbles to form in concrete.

STEM Connection

Math

Volume Calculations

Mathematics is about more than just numbers. The units of measurement are also important. If you multiply six peanuts times seven grapefruit, mathematically the answer is 42 peanut-grapefruits. Since there is no such thing as peanut-grapefruit, however, the calculation is meaningless. When calculating volume, multiplying measurements given in inches with measurements given in feet results in a meaningless unit of measurement such as inch-inch-feet or inch-feet-feet.

The formula for calculating the number of cubic yards of concrete required for a project is:

$$\frac{\text{thickness (feet)} \times \text{width (feet)} \times \text{length (feet)}}{27\ \text{ft.}^3/\text{yd.}^3} = \underline{\qquad}\ \text{cubic yards}$$

A concrete wall is being made that measures 6″ thick, 8′ tall, and 56′ 9″ long.

$$\frac{0.5' \times 8' \times 56.75'}{27\ \text{ft.}^3/\text{yd.}^3} = \frac{227\ \text{cubic feet}}{27\ \text{ft.}^3/\text{yd.}^3} = 8.4\ \text{cubic yards}$$

It is important to check your calculations several times. This way you will be certain your answer is correct and the correct amount of concrete will be delivered. For example, what would happen if instead of using 6″, you mistakenly read the number as 6′?

$$\frac{6' \times 8' \times 56.75'}{27\ \text{ft.}^3/\text{yd.}^3} = \frac{2724\ \text{cubic feet}}{27\ \text{ft}^3/\text{yd}^3} = 100.1\ \text{cubic yards}$$

If the concrete were ordered based on this calculation, 12 times as much concrete as is needed would be delivered to the site! This could be a very costly error and illustrates the importance of checking and rechecking math calculations.

Steel Reinforcing Bars

Compression occurs in an object when forces push on an object. **Tension** occurs in an object when forces pull on an object. Concrete is much stronger in compression than in tension, **Figure 6-2**. The tensile strength of concrete is improved using **reinforcing bars**, or **rebar**, **Figure 6-3**. Rebar is made of steel. The surface is often deformed to make the concrete adhere better. Additional information about rebar and other materials used to reinforce concrete is included in Chapter 7, *Metals*.

compression: Force that pushes on an object.

tensile: Force that pulls on an object.

reinforcing bars (rebar): Steel bars used to increase the tensile strength of concrete.

Figure 6-2. Concrete cracks in tension before it crushes in compression.

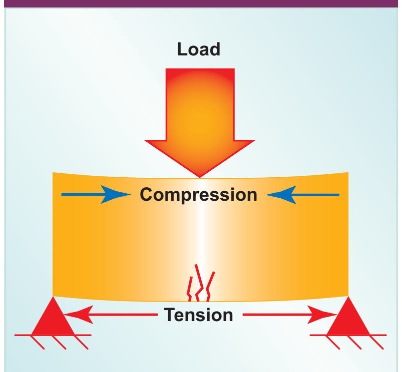


Figure 6-3. Steel reinforcing bars are used in the columns and floor of this concrete foundation. *(Bob Dale)*

Concrete Properties

Material properties determine how materials should be used. Often more than one property is considered before a material is selected.

The main properties engineers look for in concrete are strength, watertightness, durability, and workability.

- Strength—Concrete must be able to carry heavy loads and must not wear away, **Figure 6-4**.
- Watertightness—High-quality concrete resists water absorption. However, all concrete will absorb some moisture. Excessive absorption together with freezing temperatures can damage concrete.
- Durability—Concrete must provide long life and minimal upkeep on construction projects such as interstate highways and runways.
- Workability—Workable concrete flows in and around steel reinforcing rods and into the corners of forms, **Figure 6-5**. Concrete that is not workable causes gaps around rods and holes in corners of forms, weakening the concrete and creating a poor appearance.

Figure 6-4. A concrete bridge must support heavy loads.

Figure 6-5. With the help of vibration, workable concrete flows in and around the layers of steel rebar on this bridge deck. *(CMI)*

Concrete Quality

The quality of the materials used to make concrete directly influences the quality of concrete. Quality concrete depends on:

- The materials from which it is made.
- The way it is mixed.
- How it is placed and finished.
- The curing procedures.

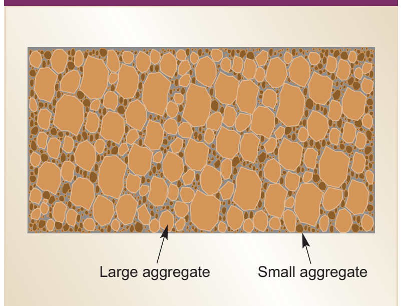
Portland cement used in concrete must be dry and in powder form. Do not use Portland cement that has been exposed to moisture and has become hard. The aggregate needs to be strong, free of foreign materials, varied in size, and capable of making a strong bond with the cement paste. Finally, the water needs to be clean and relatively free of sulfates.

Different proportions of Portland cement, fine and coarse aggregate, and water create critical quality differences in concrete. Small increases in the proportion of Portland cement increases compression strength. Various sized aggregate fills space inside the form completely, requiring less cement paste to bond the mixture together, **Figure 6-6**. Extra water makes concrete easy to work but reduces its strength, durability, and watertightness.

Concrete needs to be thoroughly mixed. The mixing process should coat each piece of aggregate with cement paste. The full range of different sized aggregate should be uniformly distributed throughout the mixture. Excessive mixing and delays in placing concrete can negatively affect quality. This is because once the Portland cement contacts water, it begins to cure.

Concrete needs to be placed in the form so the distribution of aggregate remains unchanged. Once the concrete is in the form it must be consolidated. Consolidating fills air pockets and voids in the finished product.

Figure 6-6. High-quality concrete requires aggregate of varying sizes to fill most of the space. Portland cement paste fills the remainder of the space and bonds the pieces of aggregate together.



Proper curing improves the strength, watertightness, and weather resistance of concrete and requires time, temperatures above freezing, and moisture. **Figure 6-7** shows how time and moisture affect strength of concrete. Concrete is kept moist by sprinkling with water, by applying curing compounds to the surface, or by covering the concrete with sheets of plastic or other materials. In cold weather, fresh concrete must be kept from freezing. This is done by covering the completed job and providing supplemental heat.

subgrade: The leveled surface on which footings and some concrete floors and sidewalks are placed.

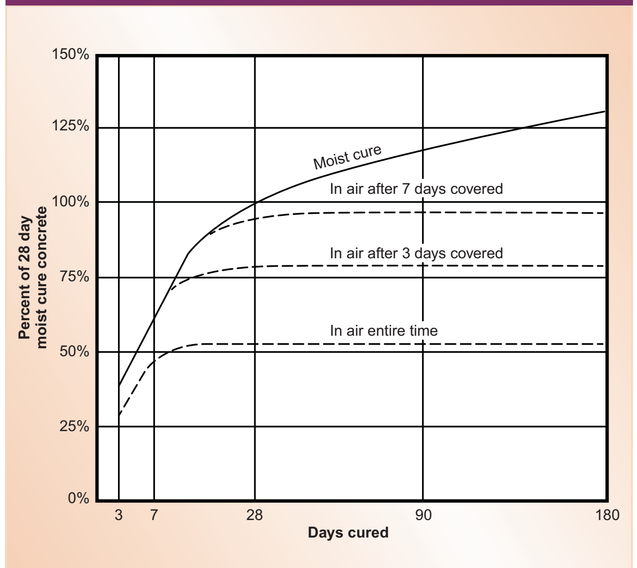
Working with Concrete

Concrete work requires a sequence of four steps: preparing, placing, finishing, and curing. The sequence is important for creating a quality concrete product.

Preparing Subgrade and Forms

Subgrade is a leveled soil surface that provides uniform support for concrete slabs and footings. The subgrade must be placed at the correct elevation. The subgrade should be compacted and moist. A moist subgrade does not absorb water from fresh concrete.

Figure 6-7. Twenty-eight days is generally considered sufficient time for concrete to reach full strength. Notice that concrete continues to gain strength even after 180 days, if moisture is present.



form ties: Component that attaches to a wall form to maintain the correct wall thickness and prevent wall forms from separating when filled with concrete.

Forms for concrete should be leveled and well braced, **Figure 6-8**. Forms for footings, concrete floors, and sidewalks are often made from boards standing on edge. They are held in place by stakes driven in the ground along the outside of the board, **Figure 6-9**. Forms for concrete walls consist of panels on each side of the wall that are joined by form ties. **Form ties** maintain the correct thickness of the wall, **Figure 6-10**.

Forms should be clean and joints should be tight to contain the liquid concrete. Form oil is sprayed on the form surfaces that will be in contact with concrete to facilitate removal and cleaning. Reinforcement for footings, floors, and other concrete placed directly on the ground should be in place and off the subgrade the correct distance. Rebar in walls is tied in place before the inside form panels are put in place.

Figure 6-8. You can see a firm subgrade, some reinforcing mesh, and part of a form. The black expansion joint along the wall allows the concrete to expand during hot weather without buckling.

Figure 6-9. Stakes nailed to 2 × 4s hold these sidewalk forms in place.

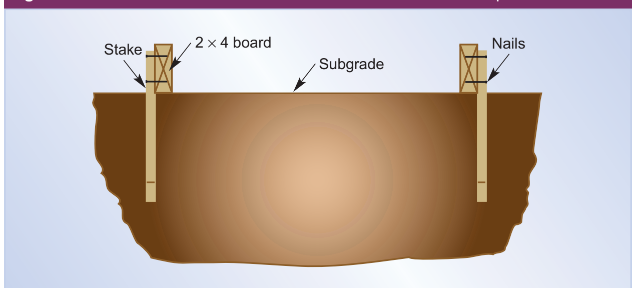
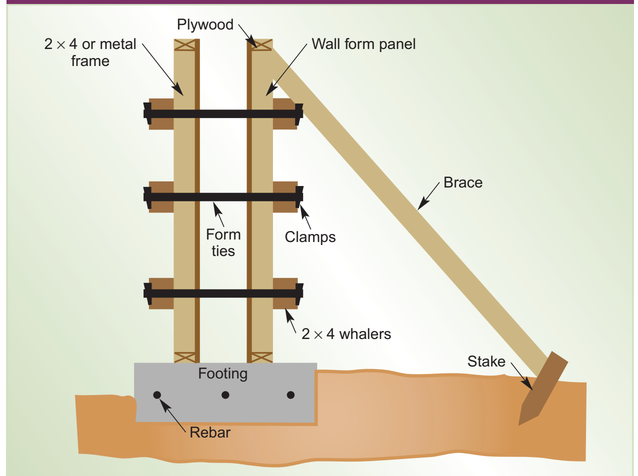


Figure 6-10. Forms are secured with whalers and clamping devices attached at the ends of the form ties. Forms are braced to maintain proper alignment.



STEM Connection

STEM

Science

Hydration Process

Hydration is a chemical process in which water combines with other elements from a compound with different characteristics. In the case of concrete, the hydration process begins as soon as water is added to the Portland cement. As a result, the concrete needs to be placed and consolidated before it sets. The concrete is said to be set when it will support weight. Finishing operations can continue for a short period of time after the concrete sets.

Curing is the final stage of hydration. During this stage, chemical bonds are formed between Portland cement particles and between the Portland cement and aggregate. The result is a solid, rocklike mass. There is plenty of water in a typical batch of concrete for complete curing. However, surface evaporation and absorption into the sub-base may result in insufficient water being available for complete hydration. Therefore, keep the surface damp by misting, covering the new concrete for an extended period of time, or spraying the surface with curing compound.

Most of the hydration and strength gain in concrete takes place in the first month after it is placed and finished. However, hydration continues at a slower rate, for many years.

cubic yard: A volume measurement equal to 27 cubic feet.

Estimating Volume

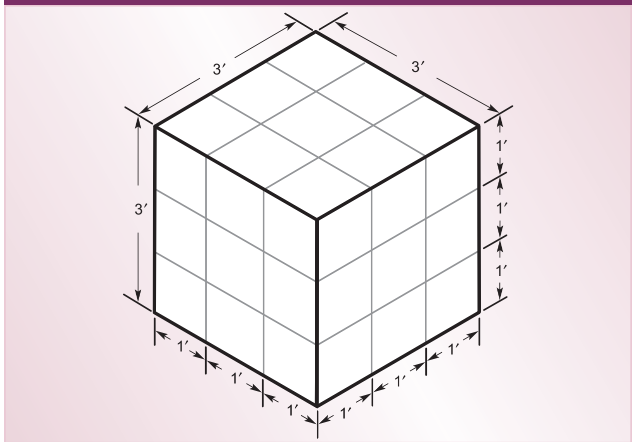
Ready-mix concrete is a type of concrete that is produced in a factory, using carefully controlled proportions of Portland cement, aggregate, and water to meet the specifications of the job. It is delivered to the work site in a transit-mix truck. It is sold by the **cubic yard**, **Figure 6-11**. But form dimensions are typically measured in feet and inches. Use the following formula to calculate cubic yards when all dimensions are given in feet. Convert any dimensions given in inches to feet before entering the numbers into this formula.

$$\frac{\text{thickness (feet)} \times \text{width (feet)} \times \text{length (feet)}}{27 \text{ ft.}^3/\text{yd.}^3} = \underline{\qquad} \text{ cubic yards}$$

Assume a concrete wall is being made that measures 6″ thick, 8′ tall, and 56′ 9″ long. The first step is to convert all given dimensions from inches to their equivalent in feet: 6″ = 0.5′ and 56′ 9″ = 56.75′. Now enter the dimensions into the formula:

$$\frac{0.5' \times 8' \times 56.75'}{27 \text{ ft.}^3/\text{yd.}^3} = \frac{227 \text{ cubic feet}}{27 \text{ ft.}^3/\text{yd.}^3} = 8.4 \text{ cubic yards}$$

Figure 6-11. A cubic yard is 3′ × 3′ × 3′ or 27 cubic feet.



SAFETY TIP

Wet concrete is highly alkaline and can cause chemical burns. Avoid contact with the skin and eyes. Use waterproof gloves, kneepads, and boots. Safety glasses or goggles are also highly desirable. If wet concrete comes in contact with the skin, wash the area thoroughly.

Dry Portland cement is a very fine powder and should not be inhaled. Use a dust mist respirator when working with this material.

Mixing Small Quantities

When only a small quantity of concrete is needed for a job, it can be mixed by hand or in a small, portable mixer. Premixed concrete can be purchased in bags that weigh approximately 80 pounds. These bags yield about two-thirds of a cubic foot of concrete.

Concrete can also be made by mixing one part Portland cement, two parts sand, and three parts gravel. Mix the dry ingredients thoroughly. Then mix enough water with the dry ingredients to make the batch workable. Add water slowly to prevent a soggy mixture.

Placing

Placing concrete involves pouring concrete as near as possible to its final location, **Figure 6-12**. Excess handling of fresh concrete can cause segregation of the aggregate, causing coarse and fine particles to separate. Concrete can be moved to the appropriate location using conveyors, pumps, buckets, chutes, or wheelbarrows.

Once the concrete is in the form, it is consolidated. **Consolidation** compacts fresh concrete so it fits snugly inside the concrete form. This is done most often using a gasoline or electric-powered vibrator. A **puddling stick**, **Figure 6-13**, is a long, thin board that is worked up and down inside wall forms to compact the concrete around reinforcing steel and into corners. A jitterbug is a tamping tool that has holes to allow cement paste and fine aggregate to rise to the top while pushing the large aggregate down, **Figure 6-14**.

consolidation: A method for compacting fresh concrete to fill all voids and air pockets inside the concrete form.

puddling stick: Long, thin boards that are worked up and down inside wall forms to compact the concrete around reinforcing steel and into corners.

Figure 6-12. This concrete is being moved using a chute. *(Photo courtesy of Constructionphotographs.com)*

Figure 6-13. A puddling stick is made from lumber.

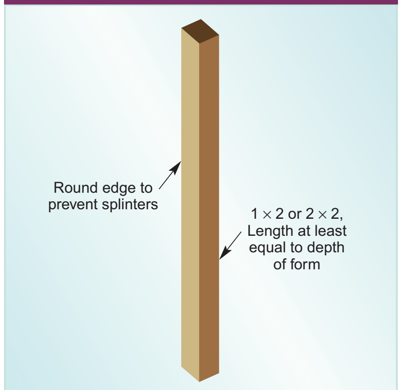


Figure 6-14. This hand tamping device is called a jitterbug. *(Marshalltown Company)*

Green Construction

Life-Cycle Assessment

A life-cycle assessment is a tool used to determine the environmental impact associated with each stage in the life cycle of a process or product. The life cycle includes all stages, from raw materials to disposal or recycling. The results of the assessment are interpreted and used by designers, contractors, and consumers to choose products that have minimal impact on the environment.

To get a better idea of what is involved in life-cycle assessment, consider what stages would need to be evaluated to assess the impact of producing just one ingredient of concrete, Portland cement. Limestone and other forms of rock or shale are major raw materials from which Portland cement is produced. Large earthmoving machines, explosives, and trucks are required to extract these raw materials from the earth and move them to the cement plant. The rock is crushed before being mixed with other raw materials and fed into a huge rotating kiln. Inside the kiln, the raw materials are heated to burn off unwanted ingredients and form a new material called clinker. Once cooled, the clinker is ground into Portland cement.

A complete life-cycle assessment would consider everything involved in each step of the process to produce Portland cement. For example, what impact does making, operating, and recycling each of the machines used to quarry limestone have on the environment? Are the gases given off by the kiln damaging the environment? What other questions do you think should be included in a life-cycle assessment for Portland cement?

Other limited forms of life-cycle assessment also being used include the following:

- Cradle-to-cradle assessments are done for products that are recycled into the original form.
- Well-to-wheel assessments are done for fuel for vehicles.
- Life-cycle energy analysis considers all the energy inputs required to produce, use, and dispose of or recycle a product. The by-products that result from making and using the energy are also included.

Finishing

Concrete finishing begins with **screeding**. Excess concrete is struck off with a straightedge. This brings the top surface of the concrete to the proper grade. The straightedge is moved back and forth across the top of the forms, **Figure 6-15**. The next step is **darbying**. A darby, **Figure 6-16**, is used to level and smooth the concrete after screeding.

In the next step, **edging**, edges are rounded over to prevent chipping. This is normally done only on slabs with an exposed edge, such as driveways and patios. In **jointing**, grooves are purposely placed in wet concrete using a grooving tool. These grooves are called control joints. These joints control the location of random cracking that may occur due to drying or to temperature changes.

Floating removes imperfections and prepares the surface for the final finish, **Figure 6-17**. It is done after edging and jointing.

screeding: A process that removes excess concrete and brings the top surface to the proper grade.

darbying: A process that levels ridges or fills voids left by screeding.

edging: Creating a radius along the edge of a concrete slab to prevent chipping and to improve appearance.

jointing: Making shallow grooves in concrete to control cracking.

floating: Process that removes imperfections and prepares the surface for the final finish.

Figure 6-15. Screeding is done immediately after concrete is spread to level and help consolidate concrete slabs.

Figure 6-16. A darby is used to level and smooth concrete. *(Marshalltown Company)*

Figure 6-17. A long handle attached to a float allows the concrete finisher to level and smooth a concrete surface from outside the forms. *(Marshalltown Company)*

troweling: Process that produces a dense, smooth, hard surface.

curing: A chemical process that causes concrete to become a solid.

slump tests: Measure the consistency of batches of concrete.

slump cone: A device that holds concrete for a slump test.

Final finishing, called **troweling**, is done with steel trowels, brooms, and other tools. Steel hand trowels are used to produce a smooth finish. A broom is used to produce a slip-resistant finish for sidewalks and roadways, **Figure 6-18**.

Curing

Curing, the hardening of concrete, requires moisture. Concrete that dries too quickly will not reach full strength. Covering finished concrete with plastic sheets or periodically misting the surface with water is essential to proper curing. Another alternative is to spray the surface with a waterproof coating called curing compound to prevent water in the concrete from evaporating too quickly.

In general, concrete should be allowed to cure as long as practical before being put into service. For example, concrete made with Type I Portland cement needs at least seven days of controlled curing.

Remove forms early to allow patching as soon as possible. However, the concrete must not be too fragile when forms are removed.

Testing Concrete

Two types of tests are commonly used when working with concrete. **Slump tests** measure the consistency of batches of concrete, indicating the workability of the concrete as it goes into the form. Compression tests measure the strength of cured concrete.

Slump tests are done by carefully filling and consolidating concrete in a slump cone. Once the concrete is consolidated, the top is leveled off and the **slump cone** is carefully removed from the concrete. The difference in height between the slumped concrete and the cone is measured, **Figure 6-19**. This measurement is the slump of the batch of concrete. If the slump is less than 1″, water needs to be added to the mix to make the concrete more workable. If the slump is greater than 5″, aggregate and Portland cement need to be added to improve the quality of the cured concrete.

Figure 6-18. A broom finish produces a skid-resistant surface.

Compression tests measure concrete's ability to withstand loads placed on it. Several cylinders are carefully filled with the concrete that is being placed. The cylinders are allowed to sit for at least 24 hours, but most testing typically takes place after seven days of curing. At that time, the concrete is removed from the cylinder and compression force is applied to the concrete, **Figure 6-20**. The force needed to crush the cylinder is measured. Two more cylinders are tested after 28 days of curing. A fourth cylinder is held in reserve in case additional testing is required.

compression test: Measures the compression strength (resistance to crushing) of concrete.

Figure 6-19. A slump of less than 1″ indicates stiff concrete that will be difficult to consolidate. A slump of more than 5″ indicates too much water in the concrete.

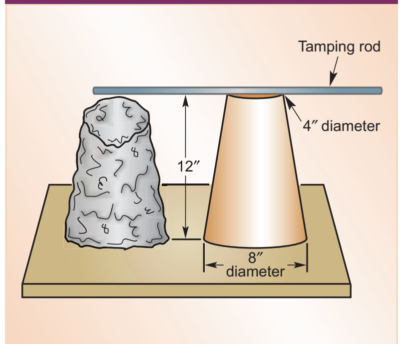


Figure 6-20. A compression test measures the compression force required for the concrete sample to fail.

Technology Link

Manufacturing Portland Cement

The dry process for manufacturing Portland cement involves the following steps.

- Step 1—Various raw materials, such as limestone, shale, clay, and sand, are crushed. Each raw material is then stored separately.
- Step 2—These raw materials are ground into powder and then blended in the required proportions. Dust collectors are used during this step to reduce air pollution.
- Step 3—Raw materials are fed into a rotating kiln. The kiln heats the raw materials, changing them into cement clinker. Heat escaping from the rotating kiln is used to preheat the raw materials.
- Step 4—Clinker is mixed with gypsum and ground into Portland cement.

In a variation of the manufacturing process, water is added during the grinding process (Step 2) to make slurry. The slurry is fed into the kiln. Other than this step, the processes are essentially the same.

A Portland cement manufacturing plant is very large. The rotating kiln is the largest piece of equipment. It is basically a large (up to 12′ in diameter) nearly horizontal steel pipe that is as much as 500′ long. The kiln is lined with firebrick to withstand the 2700°F (1482°C) temperature required to change the raw material into cement clinker.

Summary

Concrete is made by mixing Portland cement, fine and coarse aggregate, and water. Admixtures can be used to change the characteristics of concrete. Steel reinforcing bars are used to improve the tensile strength of concrete. The quality of concrete is determined by the materials from which it is made, the way it is mixed, how it is placed and finished, and the curing procedures employed.

Concrete forms need to be level and well braced. The inside of the form should be clean and coated to aid in form removal. Concrete should be placed in the forms carefully to avoid segregation of fine and coarse aggregate. Consolidating removes air pockets and voids. Finishing involves screeding, darbying, edging, jointing, and troweling. Curing, the final step, requires time, above-freezing temperatures, and the presence of moisture.

Test Your Knowledge

Write your answers on a separate piece of paper. Do not write in this book.

1. List the three ingredients in concrete.
2. What type of Portland cement is used to make concrete that cures quickly?
3. In the Western United States, soils tend to contain ______, so Type V Portland cement is often used when mixing concrete.
4. The ______ in concrete consists of fine sand and stones.
   A. admixture
   B. mixture
   C. aggregate
   D. None of the above.
5. True or False? Air-entrained concrete contains an admixture that causes small air bubbles to form in concrete.
6. Steel reinforcing bars increase the ______ strength of concrete.
7. Name four important properties of concrete.
8. List four factors that determine the quality of concrete.
9. Devices that maintain and control the thickness of a concrete wall are known as ______.
10. What formula is used to calculate cubic yards?
11. True or False? Moving fresh concrete a long distance does not cause any problems with the concrete.
12. For concrete to cure, ______ must be present.
13. The results of a ______ test indicate the workability of a batch of concrete.
    A. slump
    B. compression
    C. strength
    D. smoothness

Activities

1. Visit a building center or other retail outlet that sells concrete finishing tools. Select one float, one steel trowel, one jointer, and one edging tool. List each type of tool, the brand name, the price of each tool, and the reason you chose that tool.
2. Visit a building center to see what type of concrete reinforcing material they sell. Make a list of the diameter, length, and cost of the rebar that is available. Also, look for welded wire fabric. List available sizes and cost.
3. Visit a building center and examine the available premixed concrete products and cement. List the name of the product, the size of the bag, and the cost.
4. Visit a construction site where concrete work is underway. Do not go on the site. Instead, study the site from the street or sidewalk. Make a sketch of a concrete form for a footing, driveway, sidewalk, or a concrete wall. If you select the wall form, limit your sketch to an end or section views.
5. Visit a construction site where concrete work is underway. Do not go on the site. Instead, study the site from the street, or sidewalk. Make a list of the tools and equipment that are being used to place and finish concrete. If you do not know the name of something, make a simple sketch of the device and write a description of what the device is used to do.

This concrete finishing machine has two sets of blades. *(Photo courtesy of Constructionphotographs.com)*