UNIT 3
Building Foundations

In this Unit:

Hands-On Math Project Preview

Checking for Square

After completing this unit, you will research the regulation size for a basketball court, volleyball court, or soccer field. You will then use the 3-4-5 rule to check a court for square.

Project Checklist

As you read the chapters in this unit, use this checklist to prepare for the unit project:

- ✓ Identify the different methods for checking the square.
- ✓ Describe the importance of laying foundations square.
- ✓ Think about what can happen to a house if the foundation is not square.

Go to **glencoe.com** for this book's OLC. Find the WebQuest activity for Unit 3 called "Understanding Concrete."

Construction Careers Cement Mason

Profile Cement masons are structural workers who place concrete. They also set and align the forms that hold concrete. They may also make concrete beams, columns, and panels.

Academic Skills and Abilities

- mathematics
- blueprint reading
- geometry
- interpersonal skills
- mechanical drawing

Career Path

- on-the-job carpentry training
- apprenticeship programs
- trade and technical school courses
- certification

Go to **glencoe.com** for this book's OLC to find more information about carpentry and construction careers.

Explore the Photo

A Firm Foundation Concrete is often used as a building material. *What structures have you seen that are made with concrete?*

CHAPTER 8

Concrete as a Building Material

Section 8.1
Concrete Basics

Section 8.2
Working with Concrete

Chapter Objectives

After completing this chapter, you will be able to:

- **List** the characteristics of concrete that make it a useful construction material.
- **Restate** the basic ingredients of concrete.
- **Identify** the five basic types of cement.
- **Describe** how to mix a small batch of concrete from a pre-mix.
- **Describe** how to place concrete.
- **Name** the two basic types of steel reinforcement.

Discuss the Photo

Work Quickly When various concrete ingredients are mixed with water, the material begins to harden and should be placed in forms right away. *What might concrete be used for?*

Writing Activity: Writing Clear Questions

Locate a local supplier of Portland cement. Contact the company via e-mail or regular mail and ask what types of concrete admixtures are most frequently requested in your area. Be sure that your question includes the specific information you are looking for. Restate your question and the answer you found in a two-sentence summary.

Alan Klehr/Churchill & Klehr Photography

Chapter 8 Reading Guide

Before You Read Preview

Concrete is an extremely versatile and strong material that is used in nearly every residential construction project. Choose a content vocabulary or academic vocabulary word that is new to you. When you find it in the text, write down the definition.

Content Vocabulary

- concrete
- hydration
- Portland cement
- admixture
- crazing
- efflorescence
- slump test
- consolidation
- chair

Academic Vocabulary

You will find these words in your reading and on your tests. Use the academic vocabulary glossary to look up their definitions if necessary.

- techniques
- series
- minimum

Graphic Organizer

As you read, use a chart like the one shown to list the characteristics of concrete. Add rows as needed.

Characteristics of Concrete
1.
2.
3.
4.
5.

Go to **glencoe.com** for this book's OLC for a downloadable version of this graphic organizer.

Academic Standards

Science

Physical Science: Chemical reactions (NSES)

Physical Science: Motions and forces (NSES)

English Language Arts

Apply strategies to interpret texts (NCTE 3)

Apply knowledge of language structure and convention to discuss texts (NCTE 6)

Conduct research and gather, evaluate, and synthesize data to communicate discoveries (NCTE 7)

Mathematics

Problem Solving: Solve problems that arise in mathematics and other contexts (NCTM)

Algebra: Use mathematical models to represent and understand quantitative relationships (NCTM)

Algebra: Represent and analyze mathematical situations and structure using algebraic symbols (NCTM)

Industry Standards

Constructing Concrete Forms

Reinforcing Concrete

NCTE National Council of Teachers of English

NCTM National Council of Teachers of Mathematics

NSES National Science Education Standards

Section 8.1

Concrete Basics

Understanding Concrete

What are the components of concrete?

Concrete is a hard, strong building material that is made by mixing cement, coarse aggregate (usually gravel or crushed stone), fine aggregate (a granular material, such as sand), and water in the proper proportions. When these materials, shown in **Figure 8-1**, are combined, a chemical reaction called hydration takes place, which causes the concrete to harden. **Hydration** is a chemical reaction that occurs when water combines with cement. This chemical reaction generates heat as the concrete cures (hardens).

Builders can alter concrete's characteristics by changing the proportion or type of ingredients or by adding other materials. The strength and usefulness of concrete depend on the quality and type of materials used in the mix. The strength of concrete is also affected by the curing methods and the curing time.

Figure 8-1 Concrete Ingredients

Basic Mix The basic ingredients of concrete are: **A.** Portland cement, **B.** fine aggregate, **C.** coarse aggregate, and **D.** clean water.

The fine and coarse aggregates in a concrete mix are its inert (inactive) ingredients, while cement and water are its active ingredients. Material is not considered concrete unless all four of these ingredients are present. For example, if the coarse aggregate is missing, the resulting material is called *mortar* or *grout*.

Advantages of Concrete

Concrete has been used as a building material for thousands of years. For example, you can see concrete in Roman architecture. Concrete has the following positive characteristics:

- It has tremendous *compressive strength*, which is the ability to withstand pushing forces.
- It is resistant to chemicals.
- It will not rot or be damaged by insects.
- It hardens even under water.
- When properly cured, it withstands extreme heat and cold.
- It can be formed into almost any shape.
- It is widely available and fairly inexpensive.

In residential construction, concrete is used primarily as a foundation material, as shown in **Figure 8-2**. This use takes advantage of concrete's compressive strength. It is also used for sidewalks, driveways, entry steps, floors, and even kitchen countertops.

Portland Cement

Roman builders obtained natural cement from pumice, a mineral deposited on the slopes of volcanoes. When mixed with

Joe Mallon

Figure 8-2 A Concrete Foundation

Placing Concrete Concrete is delivered to the job site and placed into foundation forms.

water it formed a hard, durable substance. The cement used in modern concrete is called **Portland cement**. It is a manufactured substance that is created using heat. It got its name from being similar in color to Portland stone, an English limestone used for constructing buildings. Various types of Portland cement have different strength characteristics.

Manufacturing Portland cement consists of compounds of lime (calcium oxide) mixed with silica (silicon dioxide) and alumina (aluminum oxide). The lime comes from raw materials such as limestone, chalk, and even coral or seashell deposits.

To make Portland cement, the raw materials are crushed and then ground to a powder. They are then mixed in various proportions, based on the desired characteristics of the end product. The mixture is heated in a large kiln (oven) to approximately 2,700°F (1,482°C) or more. Heating changes the chemical composition of the ingredients and they form small lumps called *clinker*. A small amount of gypsum (no more than 5 percent) is added to the clinker. The resulting mixture is then pounded into the fine powder we call cement.

Basic Types There are five basic types of Portland cement. They are standardized in the United States by the American Society for Testing and Materials (ASTM). The basic types of Portland cement are shown in **Table 8-1**.

Table 8-1: Basic Types of Portland Cement

Type and Use	Characteristics
Type I (standard) Most general construction purposes	Economical, with a long setting time
Type II (modified) Most general construction purposes	Generates less heat during hydration than Type I Resists breaking down when exposed to sulfates
Type III (high-strength) Used where forms must be removed quickly or concrete must be put in service quickly	Gains strength faster than other types of cement
Type IV (low heat) Used only on very large concrete projects, such as dams	Unusually low heat generated by hydration prevents cracking caused by wide ranges of temperature
Type V (sulfate-resistant) Used where concrete will be exposed to highly alkaline conditions and sulfates	Resists alkalines and sulfates

David R. Frazier Photolibrary, Inc.

Specialty Cements In addition to the five basic types of cement, specialty cements are also avaliable. The following are used in new construction or remodeling:

- Self-leveling cement flows like thin syrup. It is often poured over a floor to cover tubes used in radiant heating systems. It is also used in remodeling work to level uneven subfloors.
- Hydraulic cement expands when mixed with water and hardens within minutes. It is used to plug holes and cracks in foundations.
- Anchor cement is fast-setting. It is used to secure railings and hardware in holes drilled in a concrete surface. It has a higher compressive strength than standard cement.
- Resurfacing cement is used to repair damaged concrete surfaces. Its fine aggregate allows it to be spread in thin layers.

Reading Check

List *What are the benefits of using concrete?*

Aggregates

Aggregate is granular material such as sand, gravel, or crushed stone. Fine aggregate consists of washed sand or other suitable materials up to ¼" in diameter. Coarse aggregate consists of pea gravel, crushed stone, or other suitable material larger than ¼" (see Figure 8-1 on page 218). Large aggregate pieces used in concrete should be solid. Layered material such as shale must be avoided. All aggregates must be clean and free of dirt, clay, or vegetable matter, which reduces the strength of the concrete.

The size of the aggregate varies depending on the kind of work for which the concrete is being used. In walls, the largest pieces of aggregate should not be more than ⅕ the thickness of the finished wall section. For slabs, the pieces should not be more than ⅓ the thickness of the slab. Never use aggregate that is larger than ¾ the width of the narrowest space through which the concrete will be required to pass during placement.

A large percentage of finished concrete consists of aggregate. For this reason, aggregate quality can have a significant impact on the strength of the concrete. Contaminants, such as dirt and organic material, can generally be removed by washing the aggregate with clean water before it is mixed with other materials.

Water

The water used to mix concrete must be clean and free from oil, alkali (base), or acid. A good rule to follow is to use water that is suitable for drinking. Other contaminants must be avoided as well. For example, sugar prevents concrete from hardening. Sugar might accidentally be introduced if ingredients are mixed in a container that was once used for food products.

The ratio of water to cement is an extremely important factor in the strength of concrete. As more water is added, compressive and tensile strength decrease. *Tensile strength* is resistance to forces that bend and pull.

Hydration

The chemical reaction that occurs when cement is mixed with water is called hydration. Understanding hydration is the key to

Science: Chemical Reactions

Hydration Portland cement reacts with water in a crystallization process called *hydration,* in which water combines with the compounds in the cement. The concrete continues to cure as long as water and unhydrated compounds are present in the cement. *Dehydration* is a reaction in which water is removed from a substance. What everyday or school tool can you think of that uses hydration or dehydration to work?

Starting Hint For hydration, think of materials that need water added in order to work correctly. For dehydration, think of materials that begin as a liquid and dry hard.

mixing and using concrete. Make sure the aggregate and other inert ingredients are thoroughly mixed with the cement. When the water is added, hydration between the water and the cement begins. This reaction causes the concrete to harden. Anything that slows hydration also slows the hardening process.

Notice the difference between the terms *hydration* and *dehydration*. In *dehydration*, a drying out takes place. Concrete does not dry out when it hardens, rather, a chemical reaction occurs. Concrete hardens just as well under water as in air. During the early stages of hydration, concrete must be kept as moist as possible. Premature drying causes the water content to drop below the amount needed for hydration to occur.

After a reaction stage, the initial hydration process comes to a stop. This *dormant* (inactive) period is what allows cement trucks to carry mixed concrete to the job site. Dormancy can last several hours, after which the concrete begins to harden.

Moist-Curing Moist-curing improves the strength of concrete. The surface is kept moist for at least several days after placement, if possible. This can be done by delaying the removal of formwork. It can also be done by covering the concrete with a material that retains moisture or by spraying it lightly with water or with chemicals that slow evaporation.

Concrete gains most of its strength in the 28-day period after it has been placed. However, concrete continues to gain strength for many years afterward.

Reading Check

Compare *What is the difference between hydration and dehydration?*

Admixtures

Ingredients called admixtures are sometimes added to concrete. An **admixture** is an ingredient other than cement, aggregate, or water that is added to a concrete mix to change its physical or chemical characteristics. For example, different admixtures can make concrete more workable or increase its strength, and can be added before or during the mixing process. The following are common:

Air-Entraining Admixtures These introduce tiny bubbles into the concrete, as shown in **Figure 8-3**. The bubbles increase the concrete's durability when it is exposed to moisture and frequent freeze/thaw cycles. Air-entraining admixtures are commonly added to concrete used in cold-weather climates. They also improve the material's workability.

Retarding Admixtures These make the concrete set up at a slower rate. This is useful in hot weather or when it is difficult to finish placement before the concrete normally sets up.

Accelerating Admixtures These increase the rate at which concrete gains strength. This can be important if the concrete must be put into service quickly. Calcium chloride is one type of accelerator. It is added to the mixing water in liquid form, rather than powdered form, to avoid problems caused by undissolved material.

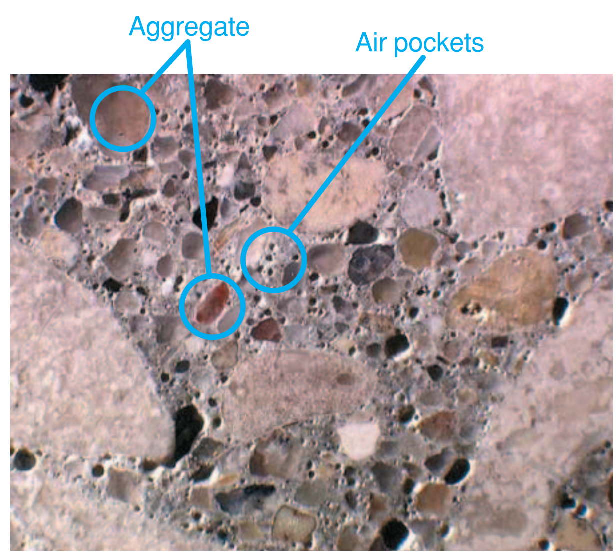

Figure 8-3 Air-Entrained Concrete
Tiny Bubbles Air-entrained concrete as seen through a microscope.

Courtesy of the Concrete Microscopy Laboratory at UIUC Paul E. Stutzman photo

Water-Reducing Admixtures These make it possible to reduce the amount of mixing water without reducing the workability of the concrete. This makes the concrete stronger.

Super-Plasticizing Admixtures These generally can do one of two things. They can make the concrete flow very easily, or they can significantly increase its strength.

Colorants

Color or pigment is sometimes added to concrete that will be used as a finished surface. An alternative method is to place a standard, uncolored layer of concrete and then immediately add a colored layer over it. A third method is to dust powdered colorant over the surface of wet concrete. As the surface is troweled flat and smooth, the colorant is absorbed into the surface. A *trowel* is a metal tool with a wide, flat blade that is used for shaping and spreading substances.

Troubleshooting Concrete

Concrete that has been mixed fully using the proper ingredients results in a durable and relatively trouble-free material. However, problems sometimes occur that can affect the strength, durability, or appearance of concrete. They are often the result of improper finishing **techniques**. Common problems include the following:

- **Crazing** is the appearance of fine cracks that appear in irregular patterns over the surface of the concrete. They typically appear within a week after the concrete has been placed and do not affect the strength of the concrete. Crazing is often caused by excessive floating or by spraying water on the concrete during finishing. Improper curing is another cause, particularly in hot or dry weather.
- *Plastic shrinkage cracks* occur mostly in concrete slabs. They appear as a **series** of shallow, parallel cracks in the surface. They are caused by the too-rapid drying of the concrete surface. The cracks rarely affect the strength or durability of the concrete.
- **Efflorescence** is a whitish crystalline deposit that sometimes appears on the surface of concrete or mortar. It is sometimes caused when salts in the concrete mix with water or moisture vapor and rise to the surface. It can occur at any time after the concrete cures substantially. It can also be caused when soluble (dissolvable in water) compounds in the soil are drawn into the concrete. Efflorescence is a cosmetic problem that generally does not affect strength or durability.
- *Cracks* that extend through the concrete can significantly reduce its strength and long-term durability. They can have many causes, including improperly compacted subgrades, excessive water in the concrete mix (high-slump), and the lack of expansion joints in large slabs. Concrete may also crack if there is not enough concrete cover over steel reinforcing. This allows moisture to reach the steel, causing rust deposits that expand.
- *Chalking* is a term that describes the formation of loose powder on the surface of hardened concrete. It is sometimes called *dusting*. The surface of the concrete is so weak that it can be crushed by surface traffic or even scratched with light pressure. It is sometimes the result of finishing the concrete before surface water (bleed water) has disappeared. It can also be caused by placing concrete directly over non-absorbative materials such as polyethylene sheet plastic, or by placing concrete in unusually cold weather.
- *Scale* is a term that describes widespread flaking of a hardened concrete surface. It is often the result of exposing the concrete to freeze/thaw extremes.

Section 8.1 Assessment

After You Read: Self-Check

1. If a material contains fine aggregate, cement, and water, but not coarse aggregate, what is the material called?
2. What is *clinker*?
3. How are plastic shrinkage cracks formed?
4. What is an admixture?

Academic Integration: Science

5. **Concrete Strength** When a material reaches the limit of its *compressive strength*, it is crushed. When a material reaches the limit of its *tensile strength*, it bends to the point that it breaks or is deformed. By itself, concrete has a comparatively low tensile strength, but a high compressive strength. With a partner, brainstorm one or two ways you could measure the compressive strength or tensile strength of a material.

Go to glencoe.com for this book's OLC to check your answers.

Section 8.2 Working with Concrete

Placement Techniques

Why is a slump test important?

The word *pour* is often used to describe the process of putting wet concrete into position. However, the term favored by the industry is *place*. An example might read: "The concrete is placed in foundation forms."

Concrete is measured by the cubic yard. Builders often shorten this to "yard." One cubic yard contains 27 cubic feet.

Mixing

Concrete can be mixed on the job from raw materials or by adding water to bags of pre-mixed dry ingredients. It can also be delivered pre-mixed. This is sometimes called a "transit" mix because the concrete ingredients are mixed in transit by a truck traveling to the job site. Another term for this is *ready-mix*. A third method is to have the concrete ingredients delivered by a small-batch truck, sometimes called a "short load" truck. Instead of mixing all the ingredients in transit, the truck carries all the ingredients in separate containers, including water. The truck operator can than blend the ingredients as needed once the truck reaches the job site.

Strength, durability, watertightness, and wear resistance are controlled by the amount of water in proportion to the amount of cement. The lower the proportion of water, the stronger the cement. However, low levels of water also make the concrete stiffer. This can make it more difficult to place.

Mixing small amounts of concrete is often done in a wheelbarrow, but any similar container may be used. A mixing hoe with holes in the blade is often used. In general, the dry ingredients are mixed together first. Water is then poured into the dry ingredients. This reduces the formation of lumps. When mixing concrete by hand, do not add the water all at once. Instead, pour in about half the amount required and thoroughly mix it with the dry ingredients. Then pour in another quarter or so and mix it evenly. Add the remaining water gradually as you mix it in. This allows you to judge the consistency of the concrete as you work, reducing the chance of adding too much water.

Using Pre-Mixed Materials When small amounts of concrete are needed, the pre-mixed dry ingredients are most often purchased in 60-lb., 80-lb., or 94-lb. sacks. When mixed with water, a 60-lb. sack yields 1 cubic foot (cu. ft.) of concrete. However, if the job requires more than 12 sacks of pre-mix, it is generally more efficient and less expensive to obtain concrete in other ways.

Because water triggers the hydration process, take care to store sacks of pre-mix under dry conditions. Small amounts of moisture can cause the cement to become lumpy. Lumps that cannot be broken up by squeezing in your hand mean the pre-mix should not be used.

It is best to store the sacks indoors. If this is not possible, they must be covered with a waterproof tarp. Stack the sacks off the ground and arrange them tightly to limit air circulation. Material in sacks that have been stacked for a long time may seem hard. This is called warehouse pack. It can be loosened simply by rolling the sack back and forth.

Mixing on Site It was once common to mix concrete on site, using separate quantities of cement and aggregate. Most builders now rely on ready-mixed concrete, but there are still times when mixing on site is preferable. This might include occasions when sites cannot be reached by a ready-mix truck.

Table 8-2: Proportions for Various Mixes of Content

Proportions		Cement Bags[b]	Aggregates	
			Fine (cubic feet)	Coarse (cubic feet)
With ¾" maximum size aggregate	Mixture for 1 bag trial batch[a]	1	2	2¼
	Materials per cu. yd. of concrete	7¾	17 (1,550 lbs.)	19.5 (1,950 lbs.)
With 1" maximum size aggregate	Mixture for 1 bag trial batch	1	2¼	3
	Materials per cu. yd. of concrete	6¼	15.5 (1,400 lbs.)	21 (2,100 lbs.)
With 1½" maximum size aggregate (preferred mix)	Mixture for 1 bag trial batch	1	2½	3½
	Materials per cu. yd. of concrete	6	16.5 (1,500 lbs.)	23 (2,300 lbs.)
With 1½" maximum size aggregate (alternate mix)	Mixture for 1 bag trial batch	1	3	4
	Materials per cu. yd. of concrete	5	16.5 (1,500 lbs.)	22 (2,200 lbs.)

[a]Mix proportions will vary slightly depending on gradation of aggregates. A 10 percent allowance for normal waste has been included in the above figures for fine and coarse aggregate.
[b]One bag of cement equals 1 cu. ft.

When concrete is mixed on the job site, the quantities of cement and aggregate must be figured separately for each cubic yard needed. **Table 8-2** shows the number of bags of Portland cement and the cubic feet of aggregates required to produce 1 cubic yard (27 cu. ft.) of mixed concrete for several mixes. **Tables 8-3** (below) and **8-4** (on page 226) show the amount of water to use in various mixes. These proportions are approximate. Always adjust the mix as needed to suit the job.

For accurate proportions, a bottomless measuring box may be used. This is a four-sided container with no top and no bottom. It has a capacity of 1, 2, 3, or 4 cu. ft. The box should be marked on the inside to show volume levels, such as 1 cu. ft., 2 cu. ft., or less. Handles on the side of the box make it easier to lift after the material has been measured.

To measure the materials, the box is placed on a mixing platform and filled with the required amount of material. The box is then lifted and the material remains on the platform.

Pails can also be used to measure proportion materials. For example, a batch of concrete could be measured by using one pail of Portland cement, two pails of sand, and three pails of gravel or crushed stone. This would be called a *1:2:3 batch.* The ingredients would be added directly to a portable drum mixer, as shown in **Figure 8-4** on page 226. Measuring can also be done with shovels or wheelbarrows, depending on the amount required. However, these methods are less precise. Ingredients should be blended until all materials are uniformly distributed.

Using Ready-Mix Most concrete is supplied to job sites by ready-mix plants. Proper amounts of cement, fine and coarse aggregates, and water are poured into the rotating drum of a truck-mounted concrete mixer. The concrete is mixed as the truck travels to the site. At the site, the concrete slides down metal chutes as it is placed into forms. This method is most economical when at least

JOB SAFETY

PROTECT YOUR SKIN Because fresh concrete is highly alkaline, it can irritate the skin and eyes. Wear gloves, rubber boots, and eye protection when mixing and placing concrete.

Go to **glencoe.com** for this book's OLC for more on job safety.

Table 8-3: Mix Proportions for Sand of Various Moisture Content

Trial Mix Aggregate Size	Gallons of Water Added to 1-Bag Batch if Sand is:				Suggested Mixture for 1-Bag Trial Batches[d]		
	Dry	Damp[a]	Wet[b]	Very Wet[c]	Bags of Cement (cu. ft.)	Aggregates (cu. ft.) Fine	Aggregates (cu. ft.) Coarse
For mild exposure: 1½" max. size aggregate	7	6¼	5½	4¾	1	3	4
For normal exposure: 1" max. size aggregate	6	5½	5	4¼	1	2¼	3
For severe exposure: 1" max. size aggregate	5	4½	4	3½	1	2	2¼

[a] "Damp" describes sand that will fall apart after being squeezed in the palm of the hand.
[b] "Wet" describes sand that will ball in the hand when squeezed but leave no moisture on the palm.
[c] "Very wet" describes sand that has been subjected to a recent rain or been recently pumped.
[d] Mix proportions will vary slightly depending on gradation of aggregates.

Table 8-4: Water Proportions for Mixing Small Batches of Concrete

Size of Batch	Pints of Mixing Water to Add			
	Very Wet Sand	Wet Sand	Damp Sand	Dry Sand
5 Gal. Water per Whole Sack of Cement				
½ sack	14	16	18	20
¼ sack	7	8	9	10
⅕ sack (18.8 lbs.)	5⅗	6⅖	7⅕	8
1⁄10 sack (9.4 lbs.)	2⅘	3⅕	3⅗	4
6 Gal. Water per Whole Sack of Cement				
½ sack	17	20	22	24
¼ sack	8½	10	11	12
⅕ sack	6⅘	8	8⅘	9⅗
1⁄10 sack	3⅖	4	4⅖	4⅘

two cubic yards of concrete are ordered. The ready-mix company usually charges a premium for smaller volumes. In those cases, a small-batch truck may be more cost-effective.

Ready-mix concrete is ordered by the number of bags of cement required per cubic yard of concrete. Five-bag mix (that is, five bags per cubic yard) is considered to be the **minimum** amount required for most work. Where high strength is needed or where steel reinforcement is used, six-bag mix is commonly specified. Another

JOB SAFETY

RESPIRATOR USE Mixing concrete is a very dusty operation. Be sure to wear a suitable respirator, particularly when mixing the dry ingredients. The respirator should be specifically designed for protection when mixing these ingredients.

Go to **glencoe.com** for this book's OLC for more on job safety.

Figure 8-4 A Drum Mixer

Portable Mixer A portable drum mixer may be used for mixing concrete on site. *Why would this tool save time and reduce labor costs?*

way of ordering ready-mix is by its compressive strength. Building plans often specify compressive strength, such as 2,500 or 3,500 psi. Ingredients are then blended to meet this requirement.

Where concrete will be exposed to moderate or severe weathering, building codes generally require stronger and more durable concrete. Such concrete may be used in sidewalks, exposed basement walls, porch slabs, carport slabs, and garage slabs. Codes may also require that the concrete be air-entrained. This concrete is better able to withstand temperature extremes and the chemicals sometimes used for melting ice and snow.

Slump Testing

After the ingredients have been mixed, a slump test is sometimes done at the job site or at the ready-mix plant. A **slump test** is a test to measure the consistency of concrete. The test should be done whenever the consistency of the concrete is of critical importance. It is often required in commercial construction and sometimes in residential construction. In a slump test, concrete straight from the mixer is placed into a small sheet metal cone of specific dimensions, shown in **Figure 8-5**.

After the concrete has been repeatedly speared with a rod to remove air pockets, the cone is lifted and removed. A measurement is then taken of how much the unsupported mass of concrete *slumps,* or loses its conical shape, as shown in **Figure 8-6**. The greater the slump, the wetter the concrete. Concrete used in paving and floor slabs might have a minimum slump of 1" and a maximum of 4". However, concrete used for columns and walls might have a slump ranging from 4" to 8". The greater slump would make it easier for the concrete to flow into narrow forms.

Placement

Concrete should be placed continuously, or all at once, whenever possible. It should also be kept fairly level throughout the area. For best results, the concrete should be consolidated. **Consolidation** is a process that removes air pockets and forces the concrete into all parts of the forms. It causes fine particles of the mix to migrate toward the forms and heavier aggregate to move away, which leaves a smooth finish on the walls when the forms are stripped. In a concrete slab, consolidation makes it easier to put a smooth finish on the top of the slab. Consolidation also helps the concrete to flow around steel reinforcing. Concrete can be consolidated with a concrete vibrator as shown in **Figure 8-7** on page 228. This portable tool is powered by a small electric motor. It is used when large quantities of concrete must be placed, particularly in wall and column forms. On smaller jobs, concrete can be consolidated by tamping it or by repeatedly spearing it with a spade, or by tapping the forms repeatedly with a hammer to create a vibration.

After placement, concrete must cure properly to gain full strength. Rapid drying reduces its strength and may damage the exposed surfaces of sidewalks and drives. If maximum strength is critical, cover the concrete with a material that will slow its loss of moisture, such as polyethylene sheets, wet burlap, or wet straw.

In hot weather, make sure the concrete is covered for at least several days after placement. In some cases the concrete can be misted with water, though it is important not to use excessive amounts. Another

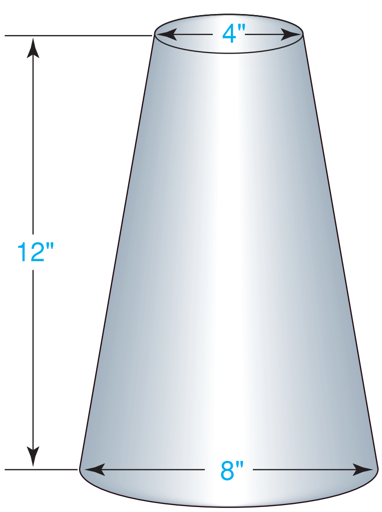

Figure 8-5 Slump Test Cone

Testing Concrete The dimensions of a test cone are critical to ensuring consistent tests.

Figure 8-6 Testing Slump

Reading Slump When the cone is removed from the concrete, the resulting slump is determined by measuring from a rod to the top of the concrete.

Ann Garvin

Figure 8-7 Vibrating Concrete

Consolidation A concrete vibrator helps to ensure that air pockets have been removed.

way to protect concrete in hot weather is to spray it with a curing compound. This is a liquid product that forms a transparent film on the concrete to reduce moisture loss.

In very cold weather, keep the temperature of the concrete above freezing until it has set. The rate at which concrete sets is affected by temperature, and is much slower at 40°F (4°C) and below than at higher temperatures. In cold weather, the use of heated water and heated aggregate during mixing is good practice. In severely cold weather, the concrete should be covered by waterproof insulating blankets. In some cases, a temporary framework of lumber and plastic sheeting can be built to protect the concrete from the cold. Heaters can be used to pump warm air into the framework until the concrete has set.

Once the dry concrete ingredients are mixed with water, there is not much time in which to place the concrete before hydration makes it difficult or impossible to work with. When the ready-mix truck shows up, all preparations for placement must be complete and all placement workers must be ready.

Pre-Placement Checklist Supervisors often fill out a *pre-placement checklist* to make sure no detail has been forgotten. This is a standardized form that lists the materials that must be on hand and the tasks that must be complete before the concrete is placed. Here are some of the questions that might appear on a pre-placement checklist:

- Is all wall formwork straight and plumb?
- Are scaffolding planks properly secured?
- Is all horizontal and vertical rebar in place?
- Is a concrete vibrator available? Is it in working order?
- Are anchor bolts and hold-downs on site?
- Are there enough shovels, rakes, and other placement tools for the crew?

Concrete can usually be placed directly by chute from the concrete truck. However, on a steep or heavily wooded site, it is sometimes impossible for the truck to get near enough to deliver the concrete by chute. In such cases, it

REGIONAL CONCERNS

Concrete and the Weather In some geographic areas, extremely hot weather is common during the construction season. Elsewhere, work must continue during extremely cold weather. Various ingredients can be added to concrete in order to counteract the effects of temperature extremes. Check with your concrete supplier several days in advance of the delivery date.

Go to **glencoe.com** for this book's OLC for more information about regional concerns.

David R. Frazier Photolibrary, Inc.

can be pumped through long, flexible pipes. The concrete is delivered from the ready-mix truck directly into the hopper of a pump truck. From there, it is pumped into the forms.

Reading Check

Explain *What effect can rapid drying have on concrete?*

Concrete Reinforcement

When should concrete be reinforced?

Both steel and synthetic fibers can be added to concrete to improve its qualities. Concrete has great strength in compression, which means that it can support huge loads placed directly upon it. Steel has excellent *tensile strength,* which is resistance to forces that bend and pull. When steel is embedded in concrete, the resulting material, called reinforced concrete, has some characteristics of both materials. Reinforced concrete has excellent compression strength and good tensile strength. Concrete footings, slabs, and walls are nearly always reinforced with steel.

Reinforcing Bar

Reinforcing steel can be purchased in the form of reinforcing bars, called *rebar,* or in the form of welded-wire fabric. Rebar, shown in **Figure 8-8**, has a circular cross-section. It has a patterned, lugged, or otherwise "deformed" surface that helps the concrete grip the steel. Most rebar for residential construction is made from uncoated steel. However, epoxy-coated rebar is sometimes used where conditions are especially corrosive. Rebar is used most often in footings and walls, while welded-wire fabric is used mostly in slabs.

Rebar comes in 20' lengths that can be cut or bent on the job site. A hacksaw or a cutting torch can cut rebar, but a rebar shear such as the one shown in **Figure 8-9** makes the job easier. A rebar shear is sometimes called a rebar cutter.

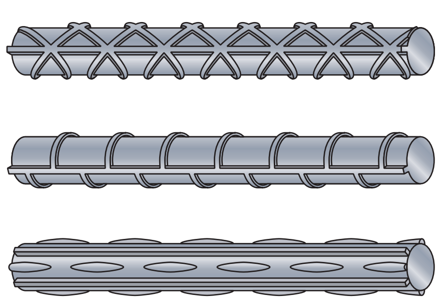

Figure 8-8 Types of Rebar
Tensile Strength Several types of rebar. The patterns help the concrete grip the bar.

Figure 8-9 A Rebar Shear
Cutting Leverage The long handle of this rebar shear provides enough leverage for smooth cuts.

JOB SAFETY

EXPOSED REBAR ENDS Rebar ends will sometimes stick out from an area of concrete that has already been placed. If they cannot be cut off immediately, the exposed ends of rebar must always be protected with a cap, shield, or some other device that will prevent accidental impalement injuries.

Go to **glencoe.com** for this book's OLC for more on job safety.

Joe Mallon

The diameter of the rebar needed for concrete varies according to the amount of tensile strength required for the concrete in the pour. **Table 8-5** shows common rebar sizes. Rebar size follows the diameter of the bar. The bar numbers represent multiples of ⅛". A number 3 rebar would be ⅜" diameter while a number 8 rebar would be 1" diameter. Diameters of residential rebar usually range from ⅜" to ⅝". Large construction projects could use a rebar size up to bar number 20, or 2½" diameter.

To be effective, any steel reinforcement must be covered by enough concrete. See **Table 8-6** for coverage guidelines. A suitable amount of concrete cover also protects the steel from rusting. If the steel reinforcement rusts, the concrete will be damaged and the strength of the installation may be weakened.

Wet concrete is dense and heavy, so workers must take steps to prevent the rebar from being dislodged as the concrete is placed. Spacers can be placed in vertical forms to prevent the rebar from shifting. In slab construction, rebar is often placed on small support devices called chairs, shown in **Figure 8-10**. A **chair** is made of noncorrosive plastic or metal and remains permanently in place after the concrete cures. The height and shape of the chair must suit the particular arrangement and size of rebar in the project.

Table 8-5: Size and Weight of Reinforcing Bars

Bar Number[a]	Bar Diameter (inches)	Approximate Weight of 100 Ft.
2	¼	17
3	⅜	38
4	½	67
5	⅝	104
6	¾	150
7	⅞	204
8	1	267

[a]Bar numbers are multiples of ⅛"

Table 8-6: Concrete Cover for Reinforcing Steel

Location	Minimum Concrete Protection (inches)
Rebar in footings	3
Rebar in concrete surface exposed to weather	2 for bars larger than No. 5; 1½ for No. 5 bars and smaller
Rebar in slabs and walls	¾
Beams and girders	1½

American Concrete Institute ACI 318, *Building Code Requirements for Reinforced Concrete.*

Chairs should be spaced as needed to prevent the rebar from sagging. Single-directional chairs support one length of rebar. Dual-directional chairs hold two lengths of rebar where they intersect. In some cases, rebar must be secured with light-gauge tie wire to prevent it from shifting off the chair when the concrete is placed. Do not use chunks of broken brick or similar materials to support rebar. These materials can draw moisture from the soil and cause the rebar to corrode over time.

Reinforcing Mesh

Welded-wire fabric is not really a fabric. It is an open mesh of wires running perpendicular to each other, as shown in **Figure 8-11**. The most common welded-wire fabric used on a residential job site has wires spaced 6" apart in two directions. This type is referred to as 6 × 6 welded-wire reinforcement. When used to reinforce a slab, the wire is first unrolled. It

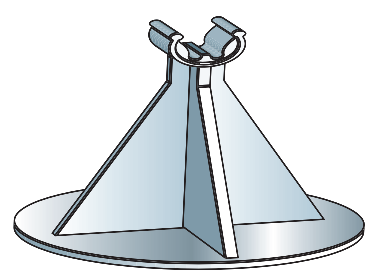

Figure 8-10 Rebar Chair
This rebar chair is a single-directional model.

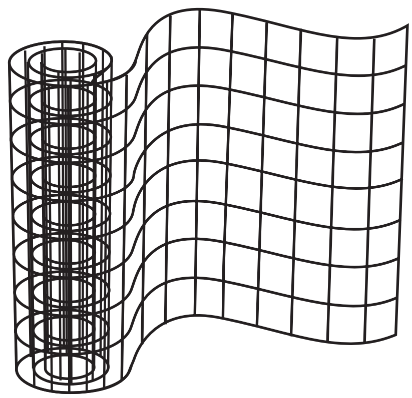

Figure 8-11 Reinforcement Mesh
Support A roll of welded-wire fabric.

is then pulled up into the concrete as the slab is being poured. A more precise technique is to support the welded-wire fabric on *wire chairs* so that the concrete can flow under it. Wire chairs for this purpose are usually between 2" and 4" in height.

Fiber Reinforcement Short synthetic fibers are sometimes mixed with concrete to reinforce it. These fibers, however, are not a substitute for steel reinforcement. Instead, they help to reduce the shrinkage cracking that occurs sometimes as concrete cures. These fibers also increase concrete's resistance to impact and abrasion, and are often added to floor slabs.

REGIONAL CONCERNS

Coastal Concrete Where concrete will be exposed to salt spray or other highly corrosive elements, such as in an ocean coast location, use corrosion-resistant rebar instead of regular rebar.

Go to glencoe.com for this book's OLC for more information about regional concerns.

Section 8.2 Assessment

After You Read: Self-Check

1. What is a slump test?
2. What precaution should be taken when placing concrete in hot weather, and why?
3. What is the purpose of the patterned surface on rebar?
4. Identify two types of reinforcement and how they are used.

Academic Integration: Mathematics

5. **Equations** How many bags of five-bag mix of ready-mix concrete are needed to fill a foundation of 25 cubic yards?

Math Concept An equation shows the equal relationship between two expressions. A variable is used for the missing information.

Step 1: Let x represent the amount of bags needed.

Step 2: Select the operation you need to solve the problem. Look for words such as "how many."

Step 3: Create an equation to represent the problem ($5 \times x = 25$) and solve for x.

Go to glencoe.com for this book's OLC to check your answers.

CHAPTER 8 Review and Assessment

Chapter Summary

Section 8.1

Concrete is one of the most common and important construction materials. It is made by mixing cement, fine aggregate (usually sand), coarse aggregate (usually gravel or crushed stone), and water in the proper proportions. Concrete hardens through a chemical process called hydration.

Section 8.2

The proportion of water to cement in a batch of concrete is extremely important in determining its strength. Concrete can be made on site from pre-mixed dry ingredients or from ingredients bought separately. It can also be ordered ready-mixed from a concrete supplier. When steel reinforcing is added to concrete, the resulting material combines compressive strength with tensile strength. Reinforcing materials come in several forms, including steel rods, rebar, welded-wire fabric, and synthetic fibers.

Review Content Vocabulary and Academic Vocabulary

1. Use each of these content vocabulary and academic vocabulary words in a sentence or diagram.

Content Vocabulary

- concrete (p. 218)
- hydration (p. 218)
- Portland cement (p. 219)
- admixture (p. 221)
- crazing (p. 222)
- efflorescence (p. 222)
- slump test (p. 226)
- consolidation (p. 227)
- chair (p. 230)

Academic Vocabulary

- techniques (p. 222)
- series (p. 222)
- minimum (p. 226)

Speak Like a Pro

Technical Terms

2. Work with a classmate to define the following terms used in the chapter: *compressive strength* (p. 218), *clinker* (p. 219), *tensile strength* (p. 220), *dehydration* (p. 221), *dormant* (p. 221), *trowel* (p. 222), *chalking* (p. 222), *scale* (p. 222), *place* (p. 223), *ready-mix* (p. 223), *slumps* (p. 227), *pre-placement checklist* (p. 228), *rebar* (p. 229), *wire chairs* (p. 231).

Review Key Concepts

3. Describe the characteristics of concrete make it useful for creating building foundations.

4. Identify the basic ingredients of concrete.

5. Name the five basic types of cement.

6. Explain how to mix a small batch of concrete from a pre-mix.

7. List the characteristics of properly cured concrete.

8. Describe the characteristics of rebar and welded-wire fabric.

Critical Thinking

9. **Analyze** Why is concrete used primarily as foundation material in residential construction?

Academic and Workplace Applications

STEM Mathematics

10. **Ratios** Use the 1:2:3 mixture to calculate how many of pounds of fine and coarse aggregate are required for 300 lbs. of cement to produce one batch of concrete.

Math Concept A *ratio* is a comparison of two numbers that shows how the proportions are related.

Step 1: Multiply the amount of cement by 2 to find the correct ratio of fine aggregate.

Step 2: Multiply the amount of cement by 3 to find the correct ratio of coarse aggregate.

21st Century Skills

11. **Communication Skills** The terms *cement* and *concrete* are often used interchangeably. However, these two terms have different meanings. Define each term in one or two sentences. Then, write two to three sentences explaining why the phrases *cement sidewalk* and *cement mixer* are inaccurate.

21st Century Skills

12. **Information Literacy: Regional Role-Play** You are in charge of deciding what concrete should be used to build a parking garage project. The project is located in Detroit, Michigan, and the client's scheduler has determined that the concrete will be placed in January. Research what temperatures you can expect during the project. List an advantage or disadvantage of the weather. What steps would you take to prevent problems with the concrete and to ensure the safety of workers during the placing of the concrete? Explain your reasoning to the client in a two-paragraph response.

Standardized TEST Practice

CERTIFICATION PREP

Multiple Choice

Directions Choose the word or phrase that best completes the statement.

13. When concrete is delivered to the job site pre-mixed, it is called a _____.

- **a.** short load mix
- **b.** small-batch mix
- **c.** transit mix
- **d.** site mix

14. The process that removes air pockets and forces the concrete into all parts of the forms is called _____.

- **a.** hydration
- **b.** consolidation
- **c.** admixture
- **d.** slump testing

15. _____ is widespread flaking of a hardened concrete surface.

- **a.** Crazing
- **b.** Efflorescence
- **c.** Chalking
- **d.** Scale

TEST-TAKING TIP

In a multiple-choice test, the answers should be specific and precise. Read the question first, then read all the answer choices. Eliminate answers that you know are incorrect.

*These questions will help you practice for national certification assessment.