Lesson 2: Factors Affecting the Quality of Fresh Concrete

Concrete has many uses in the agricultural industry, from sidewalks to buildings. When looking at concrete, the question arises, "How is concrete made?" This lesson will explore the raw materials used in concrete, how to mix concrete, the additives used in concrete, and how to test concrete to see if it has the proper consistency.

The Components of Concrete

Concrete is a compound made from several different components. The main materials in concrete are aggregates, water, and cement.

Aggregates (sand and gravel) - Aggregates typically make up 60 to 80 percent of the volume of the concrete mixture. Aggregates are classified into two main categories. Fine aggregates are those particles that are smaller than a quarter inch in size; they can pass through a number four sieve, which is a sieve with four wires per inch. Fine aggregates are typically called sand. Coarse aggregates, called gravel, are particles larger than one quarter inch in size. The sand used in concrete should be clean and relatively dry, while the gravel should be clean and uniform in size. A larger aggregate size will result in stronger concrete and more economical costs.

Aggregates have several functions. They provide a cheap filler material that adds volume to the concrete. They are also stable materials that will resist forces on the concrete and that help to maintain volume while the concrete sets and hardens.

Occasionally other compounds besides sand and gravel are used as aggregates for speciality applications. Sometimes vermiculite and pearlite, compounds naturally found in the soil, are utilized when the concrete needs to be lightweight. The resulting concrete can be sawed. Clay, shale, and crushed brick can act as insulation. Steel and iron shot may be used as aggregates in the high density concrete for radiation shielding, as in a nuclear reactor or in the walls surrounding the x-ray laboratory in a hospital or clinic.

Water - Water is another important ingredient in concrete. Water serves several purposes in the concrete mixture. It allows the concrete to be molded or shaped, aids in mixing, and plays an important role in hydration, the chemical reaction between water and cement that bonds the mixture together.

The water used in concrete should be clean. If the water has too many impurities, the quality of the concrete will suffer. Generally, if the water is potable, or drinkable, it can be used in the concrete. The water should have less than 2,000 ppm (parts per million) of total dissolved solids.

Abram's Law is an accepted rule for concrete that describes the relationship between water and concrete. As stated in Ahren's *Concrete and Concrete Masonry,* the law is "For given materials and conditions of handling, the strength of concrete is determined primarily by the ratio of the weight of mixing water to the weight of cement as long as the mixture is plastic and workable." In other words, less water is generally better in mixing concrete, as long as the mixture is workable. Too much water weakens the final concrete mixture.

Cement - Cement and concrete are often referred to as if they are the same thing, but they are not. Cement is an important ingredient in concrete. With water, it forms the glue that holds the concrete together as it forms and hardens.

Portland cement is probably the most common cement used today. Portland cement was first patented in 1824 by a man named Joseph Aspdin.

The manufacturing of portland cement involves several steps. Limestone is the base material for cement. The limestone is taken from a quarry and crushed into a fine powder. This powdered limestone is then mixed with clay or shale, and the mixture is ground again. The ground mixture is sent to a kiln, or oven, to dry. The name of this dried product is clinker. After the clinker is removed and cooled, gypsum is added, and the mixture is ground one final time to produce portland cement. Table 2.1 gives the final chemical composition of portland cement.

Five types of portland cement are commonly produced and used for different applications. Type I is for common applications. Type II is used where heat buildup is a concern, as in a thick wall or large structure. Type III, or high early strength cement, is useful when the concrete needs strength in the first two to three days after pouring, as in a driveway or walkway for a building. Type IV, or low heat cement, reduces the heat generated by hydration; it is used in confined indoor spaces. Type V, also known as sulfate resistant cement, is necessary when the concrete is poured over alkaline soils, which can decrease the durability of the concrete.

Table 2.1 - Cement Composition

Material	Percentage (%)
Lime	60-66
Silica	19-25
Alumina	3-8
Iron	1-5
Magnesia	0-5
Sulfur trioxide	1-3

Two agencies regulate portland cement and its specifications. They are the American Society for Testing and Materials (ASTM) and the Canadian Standards Association (CSA). These agencies determine the requirements for the different categories of portland cement and work to maintain concrete quality.

Mixing Concrete

The most common agricultural mixes are usually described in one of three different ways. These descriptions are useful in ordering and preparing the mixture. The first method of describing concrete mixtures refers to the number of bags of cement in each cubic yard of concrete, which is equal to 27 cubic feet of volume. Ready-mix concrete ordered through a supplier is usually ordered using this method. The three most common ready mixes and their applications are shown in Table 2.2.

A second method of referring to concrete mixes uses a ratio that shows the relative amounts of the different components of the concrete. A common mixture is 1:2:3-6. This ratio indicates that the concrete is one part cement, two parts sand, three parts gravel, and six parts water. Each part consists of a particular volume, such as one cubic foot.

The third method used to describe concrete mixes indicates the gallons of water mixed with each sack of cement. Common mixes described in this manner are 5.0, 6.0, and 7.0. In their uses, these mixes correspond to the various ready mixes already discussed, as indicated in Table 2.2. To learn the amounts of other components needed to make the cement, specific charts must be consulted to find the volume of each ingredient in a cubic yard. These charts may be available in reference books about concrete.

Concrete Additives

Sometimes circumstances may call for a particular type of concrete. For that reason, certain additives, called admixtures, are mixed into the concrete to give it special characteristics. Concrete additives fall into six main categories: air entraining additives, superplasticizers, retarding additives, accelerating additives, mineral additives, fibers, and pigments.

<u>Air entraining</u> - Air entraining additives force small air pockets in the concrete. The process of trapping air in the concrete is called air entraining. Large air pockets can weaken the

Table 2.2 - Common Mixes

Mix	Applications
5 bags of cement/yard, or 7 gallons of water/sack of cement	Foundation walls, footings
6 bags of cement/yard, or 6 gallons of water/sack of cement	House floors, dairy floors, driveways, septic tanks
7 bags of cement/yard, or 5 gallons of water/sack of cement	Concrete under severe conditions, concrete exposed to acids or severe weather

concrete, but small pockets are beneficial in several ways. Air entraining improves concrete's workability, water tightness, and finish qualities. It also increases the concrete's resistance to freezing and thawing and its resistance to salt and sulfates, which can erode the concrete. Concrete with these small air pockets is called air-entrained concrete.

Superplasticizers - These additives increase the strength of the concrete by altering it so that it needs less water to be workable.

Retarding - Retarding additives slow down the setting process, resulting in greater long-term strength.

Accelerating - This type of additive speeds up the setting of the concrete, resulting in more early strength and making the concrete less vulnerable to temperature changes during setting. They are frequently used in cold weather to force the concrete to set more quickly. One of the more common additives used today is an accelerating additive, calcium chloride.

Mineral - Mineral additives increase the strength of the concrete.

Fibers - Fibers reduce the tendency of the concrete to break along seams or at the edges. The fibers do not truly increase the strength of the concrete but help to bind the concrete together.

Pigments - Pigments change the color of the concrete. Adding certain minerals to the whole batch of concrete or only to the final layer can change the color of the concrete. Table 2.3 lists the minerals added to concrete to produce various colors.

Table 2.3 - Concrete Pigment Additives

Color	Additive
Blue	Cobalt oxide
Brown	Brown iron oxide
Buff	Synthetic iron oxide
Green	Chromium oxide
Red	Red iron oxide
Gray	Black iron oxide or carbon black

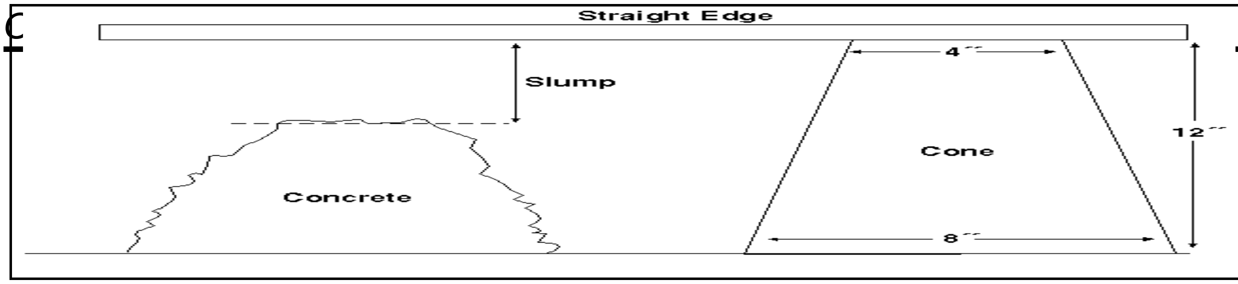
Other than calcium chloride, most additives are not commonly sold in hardware stores but are carried by local ready-mix suppliers. They can be mixed into the concrete to meet the specific needs of the project.

Slump Tests

Mixing concrete is not like cooking from a recipe, because some ingredients may already contain a certain moisture content. In mixing concrete, adding the right amount of water is important. The amount added to the mix should be decreased if the aggregates are already moist, or the concrete will be too wet. A slump test determines if the concrete is of the proper consistency; it indicates if more or less moisture is needed. The slump test is important because the test makes it possible to prepare a concrete mixture with the optimal combination of strength and workability. This test is the final step prior to pouring the concrete.

The procedure for performing the slump test is relatively simple. The test involves the use of a metal cone that is 12 inches tall, with a diameter of 4 inches at the top and 8 inches at the bottom, and open at both ends. It is placed on a flat surface with the wide end down. Prior to being filled with concrete, the cone may be moistened with oil to make cleanup easier. The cone is first filled one-third full with concrete. The concrete is tamped down with a 12-inch metal rod 25-five times to make it settle and remove any air pockets. Concrete is then added until the cone is two-thirds full, and the concrete is tamped again. Finally, the cone is filled, and the concrete is tamped for the third time. The cone is then carefully removed, and the concrete "slumps," or drops in height due to gravity.

After the concrete has stopped decreasing in height, the slump is measured. A straight edge is placed across the top of the cone, and a measurement is taken from the straight edge down to the average level of the top of the concrete, as shown in Figure 2.1. Usually, the slump should be between 1 and 3 inches. Too much slump indicates too much water, while not enough slump indicates a lack of water. If too



much water is present, adding aggregates or cement will thicken the mixture.

Adding ingredients should be the last resort in mixing concrete because it will result in weaker concrete. Ideally, the correct amounts of ingredients are used the first time. Also, most state or federal construction contracts prohibit adding ingredients after the initial mix. If the mix is not correct when it reaches the work site, the entire batch is rejected.

Summary

Concrete is a mixture of cement, aggregates (sand and gravel), and water. The relative amounts of these ingredients in the mixture depend upon the use of the concrete. Concrete mixes are described in terms of the bags of cement per yard; the ratio of cement, sand, gravel, and water; and the gallons of water per sack of cement. The seven classes of common concrete additives are air entraining additives, superplasticizers, retarding additives, accelerating additives, mineral mixtures, fibers, and pigments. A slump test is necessary to determine the proper amount of water for the concrete mixture.

Credits

Ahrens, Donald L. *Concrete and Concrete Masonry*. St. Paul, Minn.: Hobar Publications, 1976.

Boyd, James S., and Carl L. Reynolds. *Practical Farm Buildings*. 3rd. ed. Danville, Ill.: Interstate Publishers, 1993.

Cooper, Elmer L. *Agricultural Mechanics: Fundamentals and Applications*. Albany, N.Y.: Delmar Publishers, 1997.

Lindley, James A., and James H. Whitaker. *Agricultural Buildings and Structures.* Rev. ed. St. Joseph, Mich.: American Society of Agricultural Engineers, 1996.

Materials Science and Technology (MAST) Teacher's Workshop. "Concrete." Produced by the Department of Materials Science and Engineering at the University of Illinois, Urbana/Champaign. http://mach-pc66.mse.uiuc.edu/~tw/concrete/concrete.html (29 Aug. 1998).