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1982

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Shelton, David P. and Harper, James M., "G82-623 An Overview of Concrete as a Building Material" (1982).
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An Overview of Concrete as a Building Material

The general properties of concrete are discussed, as well as its components and their proportions. Includes decisions customers should consider before using concrete.

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Concrete, specifically portland cement concrete, has the qualities of strength, durability, versatility, and economy, and can be placed or molded into virtually any shape and reproduce any surface texture. It is the most widely used construction material in the world. In the United States almost twice as much portland cement concrete is used as all other construction materials combined.

History

Notable concrete projects in the U.S. include the Erie Canal, marking the opening of the first natural cement works; the first rural concrete highway near Detroit, Michigan in 1909; Grand Coulee Dam, which used nearly 10 million cubic yards of concrete, making it one of the largest portland cement concrete projects in history; and the first known tilt-up concrete building built near Des Moines, Iowa in 1912.

Demand for concrete with higher strength, better quality, and other special properties, coupled with the development of larger and faster mixer trucks, led to the emergence of the ready-mix concrete industry in the post-World War II period. The ready-mix concrete producer has made concrete an appropriate construction material for many agricultural applications.

General Properties

Concrete is a mixture of portland cement, water, aggregates, and in some cases, admixtures. The cement and water form a paste that hardens (hydrates) and bonds the aggregates together. Concrete quality is directly related to the amount and properties of the materials used, and the way that it is placed, finished, and cured.

Concrete is a versatile construction material, adaptable to a wide variety of agricultural and residential uses. With proper materials and techniques, it can withstand many acids, silage, milk, manure, fertilizers, water, fire, and abrasion. Concrete can be finished to produce surfaces ranging from glass-smooth to coarsely textured, and it can be colored with pigments or painted.

Concrete has substantial strength in compression, but is weak in tension. Most structural uses, such as beams, slats, and manure tank lids, involve reinforced concrete, which depends on concrete's strength in compression and steel's strength in tension.

Since concrete is a structural material, strength is a desirable property. Compressive strengths of concrete generally range from 2000 to 5000 pounds per square inch (psi), but concrete can be made to withstand over 10,000 psi for special jobs.

Portland Cement

Portland cement was named for the Isle of Portland, a peninsula in the English Channel where it was first produced in the 1800's. Since that time, a number of developments and improvements have been made in the production process and cement properties.

The production process for portland cement first involves grinding limestone or chalk and alumina and silica from shale or clay. The raw materials are proportioned, mixed, and then burned in large rotary kilns at approximately 2500°F until partially fused into marble-sized masses known as clinker. After the clinker cools, gypsum is added, and both materials are ground into a fine powder which is portland cement.

Today, three general types of portland cement are primarily used for agricultural applications:

- *Type I* cement is the normal, general purpose, and most common type. Unless an alternative is specified, Type I is usually used.
- *Type II* cement is modified to release less heat during hydration, and is therefore more suitable for projects involving large masses of concrete--heavy retaining walls, or deadmen for suspension bridges. It is moderately high in resistance to sulphates. Type II is replacing Type I as the basic cement in some areas.
- *Type III* cement produces concrete that gains strength very rapidly. It is very finely ground and sets rapidly, making it useful for slip-form construction and cold weather jobs.

Water

Good water is essential for quality concrete. It should be good enough to drink--free of trash, organic matter and excessive chemicals and/or minerals.

The strength and other properties of concrete are highly dependent on the amount of water and the water-cement ratio. Enough water is needed for full hydration, but too much water leads to shrinkage cracks,

voids, low strength, and generally poor quality concrete. If a mix is too stiff to handle well, and the water-cement ratio is not known, do not just add water. Either reject the batch, or add both cement and water. Re-proportion subsequent batches to produce the right consistency and workability.

Aggregates

Aggregates generally occupy 60 to 80 percent of the volume of concrete and greatly influence its properties, mix proportions and economy. Sand, gravel and crushed stone are the primary aggregates used. Recycled concrete is also used in some locations. All aggregates must be essentially free of silt and/or organic matter. They should be hard and strong. Important characteristics of a good quality aggregate include resistance to abrasion, resistance to freeze/thaw action, resistance to sulfates, correct shape and surface texture, proper gradation, density, and compressive and flexural strength. Fortunately, Nebraska has an abundance of high quality aggregate.

Admixtures

Admixtures are ingredients other than portland cement, water, and aggregates that are added to the concrete mixture immediately before or during mixing. They are used to modify certain properties of the concrete and can be classified according to their function:

1. Air-entraining admixtures.
2. Water-reducing admixtures.
3. Retarding admixtures.
4. Accelerating admixtures.
5. Cementing agents.
6. Workability agents.
7. Miscellaneous agents such as bonding, damp-proofing, permeability-reducing, grouting, and gas-forming agents.

Except for air entrainment, the desired concrete properties can often be obtained more easily and economically by selecting suitable materials rather than resorting to admixtures.

Air-entraining agents are the most commonly used admixtures for agricultural concrete. Air-entrainment produces microscopic air bubbles throughout the concrete. Entrained air bubbles dramatically improve the durability of concrete exposed to moisture and freeze/thaw action. The resistance of the concrete surface to scaling is also improved. Scaling may result from the use of chemical deicers or exposure to mild corrosive agents, such as manure or silage. Air-entrainment is recommended for all concrete used for agricultural applications, even though it has slightly lower strength than non-air-entrained concrete. The workability of fresh concrete is also improved with air-entrainment.

Retarding admixtures are used to slow the rate of concrete set or hardening. They are particularly useful for concrete that is placed during hot weather. On the other hand, accelerating admixtures, such as calcium chloride, are used to increase the rate of set--usually during cold weather. In Nebraska, flyash from coal-fired generating plants is used both as a cementing agent and/or workability admixture.

Proportions

Concrete is an exception to the statement that "the whole is the sum of its parts." For example, a small concrete batch might contain 1 ft³ cement, 2 1/4 ft³ sand, 3 ft³ gravel and 3/4 ft³ water. The sum of the individual volumes is 7 ft³, yet when mixed yields only 4 1/2 ft³ of concrete. The sand fills the voids in

the gravel, and the cement paste fills the remaining voids. Concrete volume is based on the volume of the total mixture.

The objective in designing concrete mixtures is to determine the most economical and practical combination of readily available materials to produce a concrete that will satisfy the performance requirements under specific conditions of use. To fulfill this objective, a properly proportioned concrete mix will possess these qualities:

1. Acceptable workability of freshly mixed concrete.
2. Durability, strength, and uniform appearance of hardened concrete.
3. Economy.

Since the majority of concrete used for agricultural applications is supplied by ready-mix producers, an understanding of the basic principles of mixture design is more important than the actual calculations. With this understanding, the customer can communicate better with the ready-mix supplier, and thus obtain concrete that is best suited to the project at hand. Mix design strives to produce concrete with all the desired properties from start to completion of a project.

Workability is the property that determines the ease with which freshly mixed concrete can be placed, consolidated, and finished without segregation. Workability is difficult to measure. Thus, proportioning a concrete mixture for acceptable workability is an art as well as a science. For this reason, it is important to accurately describe what the concrete is to be used for, and how it will be placed.

Table I. Minimum cement requirements and average percentages of air entrainment.			
<i>Maximum Aggregate Size (in)</i>	<i>Cement per cubic yard</i>		<i>Air Entrainment (%)</i>
	<i>pound</i>	<i>sacks</i>	
1 1/2	470	5	5 1/2
1	520	5 1/2	6
3/4	540	5 3/4	6
1/2	590	6 1/4	7
3/8	610	6 1/2	7 1/2

If acceptable materials are used, the properties of hardened concrete, such as durability, freeze/thaw resistance, watertightness, wear resistance, and strength, depend on selecting a suitable cement paste--one with a sufficiently low ratio of water to cement plus entrained air if specified. However, these properties--and thus the desired concrete quality--can only be fully achieved through proper placement and finishing, followed by prompt and effective curing.

For economy, proportioning should minimize the amount of cement required without sacrificing concrete quality. Since quality depends primarily on the amount of cement and the water-cement ratio, hold the water content to a minimum to reduce the cement requirement. Steps to minimize water and cement requirements include using 1) the stiffest practical mixture; 2) the largest practical maximum size of aggregate; and 3) the optimum ratio of fine-to-coarse aggregates. The lower limit of cement required is often a specified minimum cement content. A minimum cement content gives reasonable assurance of attaining certain desirable properties, such as workability, durability, and finishability.

Minimum cement requirements depend primarily on the maximum aggregate size used in the mix (*Table I*). A minimum amount of cement is required in order to adequately coat all aggregate particles with cement paste and provide proper bonding.

The maximum aggregate size in a concrete mix depends on the end use of the concrete. Masses such as footings can use larger aggregates than relatively thin sections such as floors. As a general rule, the maximum aggregate size should be no larger than one-third the minimum thickness of the concrete mass. For example, 1 1/8 in. would be the maximum aggregate size for a 3 1/2-in. thick floor slab. If the project involves reinforced concrete, the maximum aggregate size should also be less than three-fourths the clear space between reinforcing bars.

Because it can be easily specified and tested, compressive strength is the most universally used designation for concrete quality. However, other properties, such as durability, impermeability, and wear resistance, may be equally or more important for many agricultural applications. For these properties, the water-cement ratio, which is the weight of total water divided by the total weight of cement, is the controlling factor, and should be kept as low as practical. Fortunately, within the normal range of concrete strengths, lower water-cement ratios also give higher strengths. For agricultural applications, water-cement ratios of 0.44 to 0.50 are usually suitable. Air-entrained concrete with water-cement ratios in this range is capable of developing compressive strengths of 3500 to 4500 pounds per square inch (psi). A water-cement ratio of 0.53 should be considered as the maximum for quality agricultural concrete. Water-cement ratios of 0.44 and 0.53 are equivalent to 5 and 6 gallons of water per sack of cement, respectively.

Slump is a term that is often used when describing and/or ordering concrete. Slump is a measure of the consistency of concrete--the higher the slump, the wetter the concrete. It also indicates workability for similar mixes. The amount of slump desired depends on the type of concrete construction and the method of placement. Minimum practical slump is 1 inch. Maximum slumps for agricultural concrete that is placed and consolidated by hand methods, such as rodding and spading, are given in *Table II*. In order to obtain these slumps, it may be necessary to increase the amount of water and cement in the mix to maintain the desired water-cement ratio.

Table II. Recommended maximum values of slump for placement and consolidation by hand methods.	
Type of construction	Slump, in.*
Mass concrete	3
Pavements, slabs, footings, and reinforced foundation walls	4
Beams, columns, and reinforced walls	5
*Decrease by 1 in. for consolidation by vibration.	

Curing

Concrete that has been specified, batched, mixed, placed, and finished "letter-perfect" can still be a failure if improperly or inadequately cured. Curing is usually the last step in a concrete project and, unfortunately, is often neglected even by professionals. Curing has a major influence on the properties of hardened concrete such as durability, strength, water-tightness, wear resistance, volume stability, and resistance to freezing and thawing.

Proper concrete curing for agricultural and residential applications involves keeping newly placed concrete moist and avoiding temperature extremes (above 90°F or below 50°F) for at least three days. A seven-day (or longer) curing time is recommended if construction constraints permit. Two general methods of curing can be used:

1. Procedures that keep water on the concrete during the curing period. These include ponding or immersion, spraying or fogging, and saturated wet coverings. Such methods provide some cooling through evaporation, which is beneficial in hot weather.
2. Procedures that prevent the loss of the mixing water from concrete by sealing the surface. This can be done by covering the concrete with impervious paper or plastic sheets, or by applying membrane-forming curing compounds.

The best curing method for a particular job depends on cost, application equipment required, materials available, and the size and shape of the concrete surface. Begin the curing as soon as the concrete has hardened sufficiently to avoid erosion or other damage to the freshly finished surface. This is usually within one to two hours after placement and finishing.

Summary

Concrete is a highly versatile construction material, well suited for many agricultural applications. It is a mixture of portland cement, water, aggregates, and in some cases, admixtures. Strength, durability, and many other factors depend on the relative amounts and properties of the individual components. However, even a perfect mix can result in poor quality concrete if correct placement, finishing, and curing techniques under the proper conditions of moisture and temperature are not used.

When specifying and ordering concrete, the customer should be prepared to discuss such things as:

1. Amount of concrete required,
2. use of the concrete,
3. type of cement,
4. minimum amount of cement per cubic yard,
5. maximum water-cement ratio,
6. any special admixtures,
7. amount of air entrainment,
8. desired compressive strength,
9. amount of slump, and
10. any special considerations or restrictions with the job or at the jobsite.

Ordering concrete that is suitable for a particular job involves much more than calling the ready-mix producer and saying "send me a load of your good stuff!"

File G623 under: FARM BUILDINGS

E-1, Construction Methods

Issued December 1982; 12,000 printed.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Elbert C. Dickey, Director of Cooperative Extension, University of Nebraska, Institute of Agriculture and Natural Resources.

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