Concrete Admixtures

A menu of chemical additives can custom-tailor concrete for the job at hand.

by Bruce McIntosh

Anyone who works with concrete should know something about admixtures—their advantages and limitations, and how they affect the properties of the concrete. After all, the chances are good that you already use admixtures whenever you order concrete from your local ready-mix supplier. According to the National Ready-Mixed Concrete Association, 39 percent of all ready-mixed-concrete producers routinely use fly ash, and 65 to 70 percent of all ready-mixed concrete contains a water-reducing admixture.

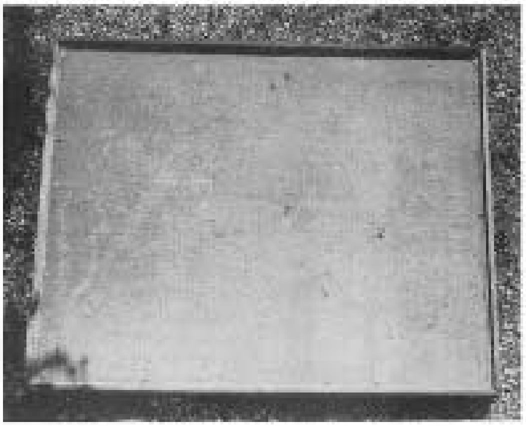
An admixture is, simply, any ingredient in concrete—other than cement, water, and aggregates—that is added during mixing. Admixtures are used to achieve special properties, such as greater workability or longer setting time.

Admixtures are as old as concrete itself. Greeks and Romans added blood, milk, or lard to concrete and mortar mixes to improve workability. Admixtures that color concrete were introduced around the turn of the century, and fly ash and air-entraining agents have been used since the early 1940s. Although there are hundreds of trade-name admixtures on the market today, they can be grouped broadly by function:

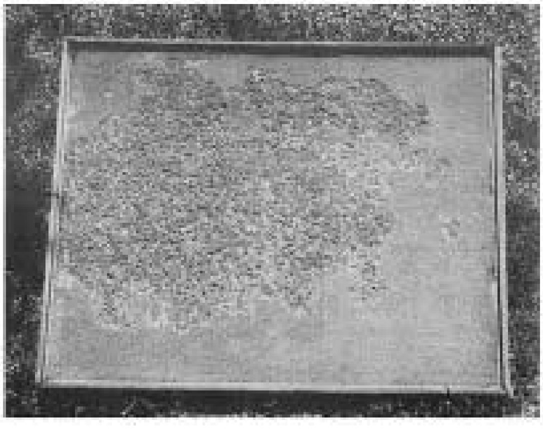
- Air-entraining agents
- Water reducers
- Retarders
- Accelerators
- Superplasticizers
- Fine mineral powders (fly ash, silica fume, and others)
- Miscellaneous agents for coloring, grouting, workability, etc.

There are probably as many reasons for using admixtures as there are admixtures. But generally, they are used either to reduce costs or to overcome some special problem in mixing, transporting, placing, or curing concrete.

As we discuss specific admixtures, bear in mind that many of the properties that admixtures produce can also be obtained by changing the concrete mix or the construction technique. For example, rapid strength can be achieved with an accelerating admixture. But you can get the same results with a richer concrete mix, by using high-early-strength cement, or by curing the concrete at higher temperatures with, say, insulating blankets. So whenever possi-



These two slabs used the same concrete mixes, but the slab shown above was air-entrained. The pictures, taken after 20 years, show severe scaling in the slab (below) without air. The two slabs are part of a long-term, outdoor durability test at the Portland Cement Association in Skokie, Illinois.



Slump & Strength

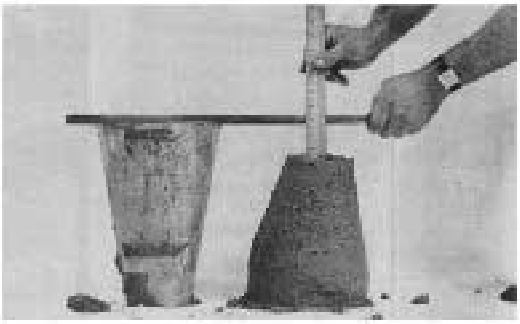
A slump cone is used to measure how fluid and, hence, how workable a concrete mix is. In a slump test, a cone is filled with concrete, then lifted off. The distance the concrete sags is the slump. The upper photo shows concrete with a slump of three inches. In the lower photo, the addition of a superplasticizer gives the same concrete mix a slump of nine inches.

Contractors have always favored concrete with a fluid consistency—or high *slump.* It's easier to place, consolidate, and finish than stiff mixes. That's why contractors often add water to concrete at the job site. But concrete with a high water content has negative aspects: lower strength, more permeability, less durability, and more shrinkage cracking.

Enter superplasticizers. These admixtures can turn stiff concrete into flowing concrete with no additional water. Superplasticizers produce high-quality, high-slump concrete while still maintaining a low water/cement ratio, which produces durable concrete with high strength.

Although a superplasticizer will add cost, you can save money in reduced labor. Flowing concrete moves easily into hard-to-reach places, through congested reinforcement, and around corners. It conforms to details in the formwork, which results in sharp corners and smooth surfaces. And since a superplasticizer makes concrete more "flowable" without adding water, shrinkage cracking is reduced. ■

—B. McI.



Superplasticizers turn the stiff mix (above) into the easily worked high-slump mix (below) without reducing strength or increasing shrinkage cracking.

ble, compare the cost of the admixture to the cost of a different mix or construction technique that gives the same result.

Air-Entraining Admixtures

Air entrainment is a must for concrete that will be exposed to freeze-thaw cycles or deicing chemicals. Under these conditions, it dramatically improves concrete's durability and resistance to surface scaling. Air entrainment also improves workability significantly. Segregation—separation of mortar from aggregate—and bleeding are reduced or eliminated.

Air entrainment creates billions of tiny air bubbles that act as internal pressure-relief valves in the hardened concrete. They let freezing water expand without building up internal pressures that could damage the concrete.

An admixture is not the only way to entrain air. Air-entraining cement—with an additive ground into it—is also used. In some cases, both an air-entraining cement and an admixture are used.

Keep in mind that you can't entrain air in hand-mixed concrete—even with admixtures or special cement. In addition to the soap-like air entrainers, mechanical agitation is necessary to produce bubbles.

Water-Reducing Admixtures

Water-reducing admixtures are used to reduce the amount of mixing water without changing the slump of concrete. (Slump is a measure of how fluid and workable concrete is. See sidebar.) Water reducers permit good flow and workability without adding excessive water and sacrificing the water/cement ratio, generally considered the key determinant of strength and durability. If the cement content is kept the same, a water reducer will increase strength.

So-called normal-range water reducers reduce the water content by 5 to 10 percent. High-range water reducers, more commonly known as superplasticizers, reduce the content by 12 to 30 percent.

Water reducers can affect other properties of concrete. Many of them retard the setting time. The most commonly used water reducer—lignosulfonate—entrains some air in the concrete. Lignosulfonates also decrease bleeding, although other water-reducing agents increase bleeding, and still others do neither. Also, some water reducers will increase the drying shrinkage of concrete.

Superplasticizers (High-Range Water Reducers)

Superplasticizers can turn normal-to-low-slump concrete into flowing concrete. For example, a superplasticizer added to three-inch-slump concrete can easily produce nine-inch-slump concrete with the same strength and other properties. Superplasticized concrete can be placed with little or no vibration or compaction.

Such flowing concrete is useful for a variety of applications:

1. Placement in thin sections
2. Placement around closely spaced or congested reinforcing steel
3. Pumped concrete
4. Tremie-pipe placements (underwater)
5. In areas where conventional consolidation methods are impractical

Superplasticizers can also be used to make normal-slump concrete with a low water/cement ratio. These admixtures can reduce the water by as much as 30 percent to produce high-strength concrete (over 6,000 psi), increase early strength gain, and provide other beneficial properties associated with low water/cement ratios.

Superplasticizers are generally more effective—but also more expensive—than normal water-reducing agents. Since some superplasticizers work for only 30 to 60 minutes followed by a rapid loss of workability or slump, they are often added at the job site. Another type, called extended-life supers, maintain increased slump for one to three hours and can be added at the batch plant.

The setting time of superplasticized concrete can be accelerated or retarded, depending on admixture chemistry, dosage rate, and interaction with other admixtures.

Retarding Admixtures

Hot weather and other job conditions that speed up concrete hardening call for the rate of concrete setting to be delayed. When fresh concrete reaches 85 or 90°F, an increased rate of hardening can make placing and finishing difficult. Retarders can offset this. (An alternative is to use cool mixing water. In extreme cases, ice may be used in place of some of the mix water.)

Retarders are also helpful on jobs where placement and finishing are difficult and time-consuming—for example, when the concrete must be transported over long distances or requires special finishing techniques, such as exposed aggregate.

Most retarders also act as water reducers, and are sometimes known as water-reducing retarders. Retarders also entrain some extra air in concrete. As you might expect, retarders reduce the rate of strength gain during the first few days, but won't affect the ultimate strength.

Accelerating Admixtures

Accelerating agents are used primarily in cool weather, which slows down concrete's setting time. Accelerators—usually calcium chloride—speed up setting time and strength development. Accelerators may also increase drying shrinkage. As mentioned previously, other options for early strength gain include using a high-early-strength cement, lowering the water/cement ratio, or curing at higher temperatures.

Calcium chloride should be dissolved in the mixing water before it's added to the concrete. If added dry, it may not dissolve completely, causing discoloration in the hardened concrete.

The amount of calcium chloride should not exceed 2 percent by weight of cement content. An overdose can cause placement problems, shrinkage cracks, and loss of strength. And keep in mind that calcium chloride is *not* an antifreeze agent for concrete. When used in allowable amounts, it will reduce concrete's freezing point by only a few degrees and should not be used as a substitute for normal methods of keeping concrete from freezing.

Calcium chloride should not be used:

1. In hot weather
2. In floor slabs that will get metallic dry-shake finishes
3. In concrete subjected to sulfate-containing water or soils
4. In concrete containing embedded aluminum, such as electrical conduit

Chloride-containing admixtures will hasten the corrosion of steel in concrete, especially in a wet environment. Building codes severely limit the amount of chloride compounds in reinforced concrete. Non-chloride accelerators are also available, but many of them are more expensive and less effective than calcium chloride.

Fine Mineral Powders

This class of admixtures contains a wide variety of powdered or pulverized materials, some natural and some by-products. By far the most widely used mineral additive is fly ash, which is the by-product of coal combustion in electric power plants. Other common mineral additives are blast-furnace slag and silica fume. Silica fume—a rather expensive by-product of the manufacture of metallic silicon or ferrosilicon alloys—is used to make high-strength concrete.

The practice of using blast-furnace slag and fly ash in concrete has been growing in the U.S. The main reason is economy. Cement is the most expensive ingredient in concrete, and fly ash is commonly used to replace some of the cement. Fly ash is also considered a waste product, and its addition to concrete mixes is sometimes regarded as a method of disposal.

Yet fly ash can improve some concrete qualities. Concrete with fly ash often needs less water for a given slump, and a lower water/cement ratio means fewer shrinkage cracks and better strength. Fly ash can also increase the ultimate strength of the concrete, although the rate of strength gain is usually slower than that of straight portland mixes. Fly ash also improves workability and reduces segregation and bleeding. Setting time is usually retarded.

There are, of course, practical limits to how much cement can be replaced with fly ash. Below a certain minimum cement content (about 500 pounds per cubic yard), concrete loses durability. And during cool weather, the slow strength gain of fly-ash mixes can impede construction.

Other Admixtures

There are many less common, more specialized admixtures. A few are worth mentioning.

Workability agents are sometimes needed for mixes that are hard to place and finish, especially if the concrete is to have a troweled finish. One of the best is entrained air, which acts as a lubricant and is especially effective in lean (low cement content) mixes. Fly ash and water-reducing agents also improve workability.

Corrosion inhibitors do what the name implies—they chemically block the corrosion of reinforcing steel in the concrete. The most common one—calcium nitrite—also acts as an accelerator. Other methods of reducing corrosion include using epoxy-coated rebar and concrete surface sealers to keep out water and deicing salts. A concrete mix with a low water/cement ratio has also been found to significantly reduce corrosion.

Dampproofing admixtures are intended to reduce the passage of water through concrete. But they are generally not effective and do not reduce the permeability of concrete to water. In fact, dampproofing agents often *increase* the permeability of concrete because they increase the water requirements of a concrete mix, which can cause shrinkage cracks. Since the passage of water through concrete can usually be traced to cracks or inadequate consolidation, the best defense against water is sound, dense concrete, properly placed and cured. ■

Bruce McIntosh is a technical writer with the Portland Cement Association.

CONCRETE GLOSSARY

ADMIXTURE—An ingredient in concrete other than water, aggregates, and hydraulic cement.

AGGREGATE—Natural or crushed stone and sand, which are the ingredients that make up the largest fraction of most concrete mixtures.

AIR ENTRAINMENT—The intentional incorporation of minute air bubbles in concrete to improve durability to freezing and thawing exposures or to improve workability. Accomplished either by use of an air-entraining admixture or an air-entraining cement.

BLEEDING—The movement of water within fresh-concrete toward the top surface and its collection there, caused by settling of the solid materials.

CALCIUM CHLORIDE—A salt, sometimes used to accelerate the setting or strength gain of concrete—but sometimes contributing to rusting of reinforcing steel or discoloration of concrete surfaces.

CEMENT—The powder (usually portland cement) which, when mixed with water and aggregate, slowly reacts chemically with the water to form the bonding agent that holds the aggregate together, producing concrete.

CURE—To retain moisture in concrete for a prescribed period and at a desirable temperature to allow the cement to chemically react with water and reach the required strength level.

DURABILITY—The ability of concrete to resist weathering action, chemical attack, and abrasion.

FLOWING CONCRETE—Concrete to which has been added a water-reducing, set-controlling admixture(s) to produce a temporarily high slump to aid in placing and consolidation.

FLY ASH—A finely divided glass-like powder recovered from the flue of a coal-burning industrial furnace. It is sometimes used as an admixture in concrete.

PERMEABLE CONCRETE—Concrete with higher-than-normal susceptibility to having water pass through it. The permeability of high-quality concrete can be one millionth that of low-quality concrete.

PLACEABILITY—Fresh concrete's capability of being easily placed and consolidated. Concrete that has good placeability is likely to have good finishing qualities, although these two qualities are not identical.

SCALING—flaking or peeling away of a surface portion of hardened concrete.

SEALER—A liquid composition applied to the concrete surface to diminish the absorption of water, solutions of deicers, or other liquids.

SEGREGATION—partial separation of the various materials that make up concrete during the transporting, handling, and/or placing operations, resulting in a nonuniform product.

SLUMP—A simple, convenient measure by a standard test method of the consistency of freshly mixed concrete.

WATER-REDUCING, SET-CONTROLLING ADMIXTURE—Chemicals added to concrete to enhance performance in both the plastic and hardened states. Includes "normal range" materials (Types A through E) and "high-range" or "superplasticizing" materials (Types F and G).

WORKABILITY—The ease of response of concrete to mixing, placing, compacting, and finishing. ■