Stay informed so you order the right concrete for the job

ORDERING READY-MIX CONCRETE

PORTLAND CEMENT ASSOC. (PCA)

by Clayton DeKorne

Concrete is a heavy material and any steps taken to make it easier to work with are understandable. Unfortunately, many finishers achieve greater workability by asking the driver to add more water to the mix. When the slab cracks, the blame passes from the contractor to the finisher and, ultimately, to the supplier, who usually winds up shouldering the responsibility.

Suppliers go to great lengths to avoid this problem. Most routinely use air-entrainment agents, chemical admixtures that form air bubbles, to help decrease *segregation* (see "Glossary" at the end of this article for italicized terminology) of the mix. Many automatically add superplasticizers, another type of chemical admixture that retards setting times and produces concrete that flows better. In hot weather, they add retarders at no extra cost. These are chemicals that slow setting times.

Mainly, a good supplier makes an effort to keep his customers well-informed about concrete. In turn, contractors should also make an effort to stay informed so they can choose the right mix for the job. Knowing what's available means you can better communicate your needs to your supplier. A good ready-mix supplier will know how to get what you want into the mix.

Specifying Cement Type

Portland cement comes in eight types (see Table 1) designated by the American Society for Testing and Materials (ASTM). However, ready-mix suppliers can usually provide only two of these, types I and II. The choices are limited since most ready-mix plants have only two storage bins, one for each type. Other types must be special ordered, adding time and money to the project.

Most suppliers say, however, that for light construction, "There is nothing that can't be done with an extra bag of cement." In fact, adding more cement per cubic yard of concrete creates a *richer mix* and lowers the *water/cement ratio*, which goes a long way toward meeting the demand for a different type. For example:

- ***In place of Type III.*** A "rapid-hardening" cement is often required in cold weather or when forms must be removed early. Adding more Type I cement to a mix will produce a similar effect by producing proportionately stronger concrete.
- ***For Type IV.*** "Low-heat" cement is only needed in massive pours, such as for gravitational dams and nuclear power plants. However, for some heavy retaining walls or abutments, Type II cement can be used. It is especially important to reduce the temperature rise of large pours in hot weather.
- ***For Type V.*** "Sulfate-resisting" cement is often required on sites where the ground water or soil contains high sulfate levels. Adding Type II cement will produce a more impermeable concrete capable of resisting all but very severe sulfate attack. Air-entrainment can also increase resistance to chemical attack.

Specifying Stronger Concrete

Compressive strength is a good indicator of a concrete's durability. But looking only at this leads to "28-day thinking," the tendency to attribute all of a concrete's properties to its 28-day compressive strength value. Other properties that are perhaps equally important include impermeability, density, and resistance to freezing and thawing. New technologies and additives that improve concrete performance should also be taken into account when choosing the best concrete for the job.

Even the weakest concrete can support the compressive loads commonly found in residential and light-commercial structures. So specifications for compressive strength are generally based more on the conditions of exposure and use than on structural loads. For example, severe weather conditions and heavy traffic

Table 1. Portland Cement Types

Type I	"Ordinary portland," for use in general construction
Type II	"Modified cement," for use in general construction when low heat or mild resistance to chemical attack is needed
Type III	"Rapid-hardening cement," for use when rapid strength development is needed
Type IA, IIA and IIIA	Designates the addition of an air-entraining agent to the cement
Type IV	"Low-heat cement," for use in massive pours when low heat buildup is required
Type V	"Sulfate-resisting cement," for use in areas where extreme sulfate attack is likely

Table 2. Compressive Strength Requirements

Structural element	Minimum compressive strength required	Practical water/cement ratios
Foundations, basement walls, and slabs not exposed to weather	2,500-3,000 psi	.55
Foundations, basement walls, and slabs exposed to weather	3,500 psi	.45
Driveways, garage slabs, sidewalks, porches, patios, and steps exposed to weather	3,500-4,000 psi	.45

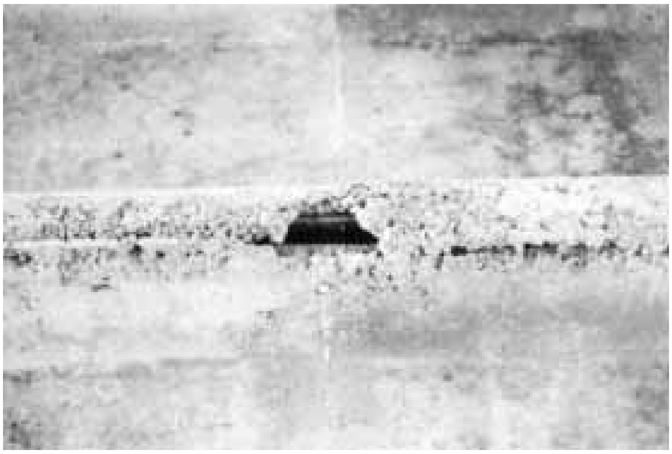

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Figure 1. *Honeycombing can be caused by poorly compacting fresh concrete or by large aggregate getting stuck between the reinforcement. To prevent the latter, the coarse aggregate should be much smaller than the smallest space between the reinforcement.*

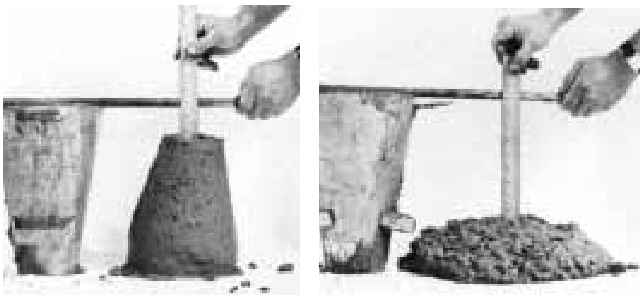

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Figure 2. *A slump test measures the workability of fresh concrete. A low-slump concrete (left) is strong but is not as easy to work with as a high-slump mix (right). To increase the slump without weakening the mix, use a water reducer or superplasticizer.*

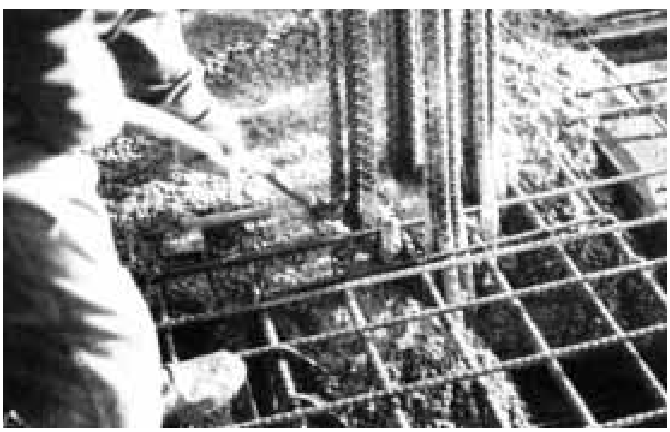

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Figure 3. *Heavy reinforcement can make it difficult to adequately compact fresh concrete. A high-slump mix can help.*

generally call for high-strength concrete (see Table 2).

Cold weather is perhaps the most destructive condition for concrete. Once water penetrates concrete, the resulting freeze/thaw cycles cause an enormous internal strain. The brittle concrete begins to scale and spall.

Deicing salts intensify freeze/thaw damage. Dissolved salts can also increase corrosion of steel reinforcement. Where deicing salts are used, such as on sidewalks and driveways, a stronger, more impermeable concrete is essential. Garage slabs are included here since water and salts dripping off cars can produce the same adverse effects.

To protect it from freeze and salt damage, concrete must be formulated so that it is impervious to water. Using a rich mix creates a denser product that better resists water entry and shields the *aggregate* particles from absorbing water. It also yields stronger concrete.

Specifying Aggregate

Aggregate functions as a dense mass to restrain the forces placed upon the concrete structure. Without suitable aggregate, concrete gradually deforms over time, a condition known as creep. The quality of the aggregate depends both on the rock type and the mixture of fine and coarse material.

Other than lightweight or heavyweight aggregate, there are not a lot of choices for the contractor. Ready-mix suppliers are limited by the type of rock that is available locally. If aggregate must be shipped into your area, concrete prices will be higher.

Different sizes of aggregate are mixed to provide the full range of particle sizes needed to fill the voids within the concrete. The fewer the voids, the denser the concrete will be and the better it will perform. Rock types used for concrete aggregate are carefully standardized by ASTM Standard C 33-86. This standard specifies a range of particle sizes and designates different sieve sizes for sorting aggregate. Your local batcher should conform to these standards.

To eliminate honeycombing in reinforced concrete, specify the largest coarse aggregate you can safely use (see Figure 1). The American Concrete Institute recommends that for walls, the largest aggregate size should be no more than one fifth the size of the thinnest section between reinforcing members. For slabs, the maximum size should be no more than one third the size of the thinnest section between members.

Getting the Right Slump

How well concrete is compacted is second only to the water/cement ratio in determining the concrete's ultimate strength. Only about 3$^1/_2$ gallons of water are needed to fully hydrate a sack of cement. But more water is needed to make a mix workable — that is, one that can be well compacted. Finding a balance between a low water/cement ratio and good workability is the key to mixing concrete.

Slump is the measure of workability, defined as the vertical distance a molded mass of fresh concrete will spread when the mold is removed (see Figure 2). Under ordinary conditions in light construction, a mix that will be compacted by hand needs, at most, a 5-inch slump. If the concrete is compacted mechanically, no more than a 3-inch slump should be specified.

But ordinary conditions do not always exist. Sometimes a concreted section will be especially thin or the forms will be clogged by heavy reinforcement (see Figure 3). Some areas may be inaccessible, such as the spread footings for piers, which are difficult to reach once a forming tube is in place. These situations require a higher slump, flowing concrete that can be adequately placed without compaction. It is important, however, to increase the slump without simply adding water, which reduces the strength of the concrete. To accomplish this, suppliers may turn to admixtures.

Specifying Admixtures

Admixtures are chemical or mineral compounds used to alter the physical or chemical properties of concrete. Chemical admixtures include air-entraining additives, water reducers, superplasticizers, retarders, and accelerators (see Table 3).

Air-entrainment. Air-entrainment for concrete was originally developed to improve its resistance to frost attack. It is now recommended for all concrete exposed to the weather. The entrained air bubbles within the concrete provide space to cushion the expansion of freezing water (see Figure 4, next page). It might seem that air-entrainment would also make concrete more porous and vulnerable to water penetration. However, because it also reduces segregation and *bleeding* and improves *workability*, air-entrainment permits a lower water/cement ratio. The net

Table 3. Admixtures and Uses

Admixture	Common active ingredients	Use
Accelerator	*Chloride:* Calcium chloride *Non-chloride:* Triethanoline (TEA), Calcium formate, Calcium nitrite	To accelerate setting time (primarily used in cold weather)
Retarder	Gypsum powder, Sugar*, Lignosulphate Hydroxycarbolic acid	To reduce setting time (primarily used in hot weather)
Water-reducer plasticizer	Lignosulfonate, Hydroxycarbolic acid	To produce a more workable mix
Superplasticizer	Sulfonated melamine formaldehyde (SMF), Sulfonated naphthlene formaldehyde (SNF), Modified lignosulfonate (MLS)	To produce flowing concrete

* **Note:** *Large amounts of sugar will completely stop the setting reaction and are often used as a kill when a mixer breaks down and cannot be emptied.*

result is a stronger, more impermeable product.

Almost every yard of concrete that leaves a batching plant today is air-entrained. Occasionally, however, a finisher will request concrete without it, such as for interior slabs. Though air-entrainment may make concrete easier to move around, it creates a "rubbery" texture that's more difficult to smooth.

Superplasticizers. To produce flowing concrete (with slumps above 7 inches), superplasticizers can be specified. Since most superplasticizers also retard the setting time of concrete, a sulfonated-melamine-formaldehyde (SMF-based) admixture is needed in cool weather. These allow a very low water/cement ratio which, in conjunction with the admixture, slightly accelerates setting times.

Retarders and accelerators. Water-reducers and retarders often have the same chemical base but serve different purposes. Like superplasticizers, water-reducers are used to produce a more workable concrete without adding water. Most high-strength concretes call for a 5-inch slump and depend on a water-reducer for workability.

Retarding admixtures are called for in warm weather when temperatures accelerate setting times. Inversely, accelerators are used in cold weather to speed the setting time and increase the rate of strength development. These also reduce the time that the concrete needs to be protected with covers and artificial heat.

Calcium chloride, the most commonly used accelerator, also improves the workability of concrete. For this reason, many finishers like to use it in *all* of their concrete. But excessive use of calcium chloride (in excess of 2 lbs. per bag of cement) can lead to severe *shrinkage* cracking and loss of strength. The material can also corrode steel reinforcement. Building codes restrict the amount of calcium chloride in reinforced concrete and forbid it in concrete containing electrical conduit. In short, if you don't need it, don't use it.

Nonchloride accelerators are gaining popularity for their noncorrosive properties. In the past they were considered too expensive, but because they do not corrode steel storage containers, many ready-mix suppliers now provide them at a lower cost. Nonchloride accelerators are less effective than calcium chloride. For example, 2% calcium chloride accelerates the setting time of portland cement by 125 minutes, versus about 100 minutes for 2% calcium formate, a non-chloride accelerator.

Admixtures are common enough now that most ready-mix plants are familiar with them and know the best proportions and procedures for adding them. Most of the chemical admixtures are added as a solution and are mechanically measured and dispensed into the mixer.

A good use for ash. Mineral admixtures, or pozzolans, are finely ground mineral substances that, when water is added, react with calcium hydroxide (the primary ingredient of cement) to form compounds with cement-like properties. Pozzolans include industrial byproducts such as fly ash, ground granulated blast-furnace slag (GGBS), and silica fume. Other types come from natural materials such as volcanic glass and tuff, diatamaceous earth, and calcined clay.

The industrial byproduct pozzolans are the most readily available — particularly fly ash, which is collected from the flues of coal-burning power plants. Fly ash and GGBS have come into their own since the Environmental Protection Agency began restricting what goes up industrial smokestacks. Pozzolans serve as a partial replacement for other materials that go into concrete, which saves both money and resources. They can also help create a high quality concrete that is extremely dense, strong, and more impermeable.

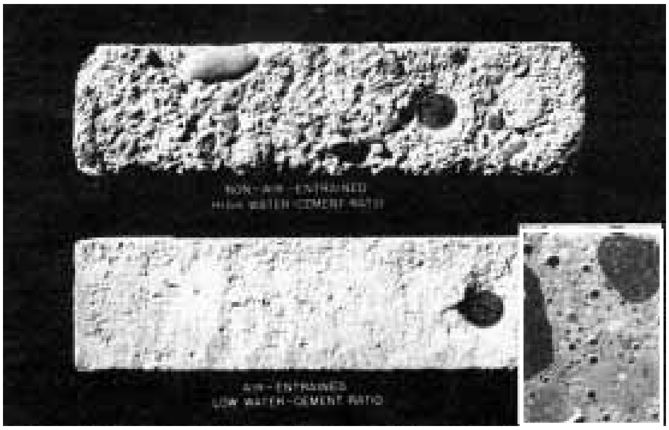

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Figure 4. *Air-entrainment protects concrete from freeze/thaw damage by introducing small air bubbles (see inset). These cushion against the expansion and contraction of water.*

Concrete made with pozzolans develops strength slowly and must be allowed to cure for long periods of time. This slow development corresponds to a small amount of heat buildup, which helps eliminate shrinkage cracking in large pours. Pozzolans are also finer than even the finest sand, so they fill in the smallest voids between particles of sand. This is especially true of silica fume, the particles of which are so small that the material cannot be bagged. Concrete with silica fume can reach 19,000 psi.

While a great deal of high-strength concrete (6,000 psi or higher) is made with pozzolans, these strengths are not needed in light construction. Yet the technology points the way toward concrete innovations that will undoubtedly affect builders in the future.

Getting Even Better

As researchers learn new techniques for improving the properties of concrete, builders will need to be even more sophisticated about what they specify. For example, new cements are now being developed that can eliminate shrinkage cracking by expanding slightly after setting. In light of such changes and the potential liabilities inherent in concrete work, a contractor can no longer simply call his ready-mix supplier and ask him to "send down a batch of concrete today." ■

Clayton DeKorne is a senior editor at The Journal of Light Construction.

Glossary

Aggregate includes both sand and gravel. *Fine aggregate* is anything smaller than 1/4 inch. *Coarse aggregate* is anything larger. *Plums* are especially large stones used as filler in large pours. Plums can be as big as one foot in diameter but, as a rule, should not be greater than one third the smallest thickness to be concreted. *Lightweight aggregate* is used to produce lightweight concrete for free-spanning structures or insulative masses. Structural lightweight aggregate includes expanded clay, shale, and slate. Lightweight insulative aggregate includes pumice, perlite, and vermiculite. *Heavyweight aggregate* is used in high-density concrete, which is used most frequently for radiation shields. Heavyweight aggregate includes barytes, iron ore, lead and steel shot, punchings, and sheared bars.

Bleeding occurs during finishing, when water is expelled from the concrete. Overworking the concrete can drive aggregate downward, which displaces water upwards, often carrying a significant portion of the cement with it. The result is a form of segregation that causes *dusting* on the surface. Severe bleeding can cause *crazing* — the cracking of the surface into small, irregularly shaped areas.

Portland cement is produced from high-calcium materials, such as limestone and chalk, and from aluminates and silicates found as clay and shale. The name "portland" derives from the cement's resemblance to that of "portland stone," a limestone quarried in England.

Rich mix has more cement in relation to the amount of aggregate than a *lean mix*.

Segregation is the separation of particles (fine aggregate, coarse aggregate, and cement) that can occur during the transportation and placing of concrete.

Shrinkage occurs in concrete in two ways: *plastic shrinkage* and *drying shrinkage*. Plastic shrinkage is the contraction of the cement paste while it is still in a "plastic" state, before setting. This is a normal effect of hydration, but it is aggravated by the evaporation of water from the surface. Rapid evaporation, either from high temperatures or excessive bleeding, will cause shrinkage cracking. As water evaporates over time from within the concrete, it undergoes drying shrinkage. This can also contribute to cracking. Shrinkage cracking can be controlled by reducing the water/cement ratio or by using a leaner mix.

Water/cement ratio is the amount of water in a concrete mix, measured in gallons per sack of cement. The water/cement ratio is a key factor in determining the strength and durability of concrete. Often water/cement ratios are given by weight. For example, 3,000 psi concrete is often specified as having a water/cement ratio of .55 (a bag of cement weighs 94 pounds, a gallon of water weighs 8.3 pounds). Move the decimal point one place to the right for a rough estimate of the gallons of water per bag of cement.

Workability refers to the consistency of the concrete mix. It describes how easily the concrete can be compacted. Because well-compacted concrete is as important to the ultimate strength of concrete as a low water/cement ratio, the key to mix design is finding a balance between good workability and a low water/cement ratio.