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concrete for the
job



ORDERING READI-MIX CONCRETE

by Clayton DeKorne

It's a sad fact that many shortcuts are taken in pouring slabs. The costs are as low as \$200 to \$300 per slab, but quality suffers.

Concrete is a heavy material and any steps taken to ease the work of pushing it around are understandable. Unfortunately, many finishers achieve grater workability by asking the driver to add more water. When the slab cracks, the contractor first turns to the finisher, who has usually purchased the concrete. Having been paid only \$200, however, how can he cover his liability? The finisher, in turn, casts his eye back to the supplier, who often shoulders the responsibility whether or not he is at fault. If he fights the finisher, he bites the hand that feeds him.

Suppliers will go to great lengths to

avoid these pitfalls. For example, most routinely add air-entrainment to help decrease segregation of the mix. Many automatically add superplasticizers to high-strength concrete. In hot weather, they add retarders at no extra cost. But mainly a good supplier makes an effort to keep his customers well-informed about concrete.

The best thing the contractor can do, besides paying a finisher well, is to stay informed about concrete so he can choose the right mix for the job. Once you know what's available, you'll be able to better communicate your needs to your supplier. A ready-mix supplier will know how to get what you want into the mix. But it helps to keep in mind some of the practical limitations he must work under.

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 - Type I and Type II. The choices are limited by the amount of storage space available at a ready-mix plant. Most plants have only two bins, one for each type. Other types must be special ordered, which, of course, adds extra time and cost.

Most suppliers will tell you, however, that for light construction, "nothing can be done with another type that can't be done with an extra bag of cement." In fact, adding more cement per cubic yard of concrete lowers the water/cement ratio (see Glossary). And

this can go a long way toward meeting the demand for another type. Some examples can illustrate this:

- **In place of Type III.** A "rapid-hardening" cement is often required in cold weather work 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 at a given point in time.
- **In place of Type V.** "Sulfate-resisting" cement is often required on sites where groundwater or soil contains high sulfate levels. More Type II cement will produce a more impermeable concrete capable of resisting all but very severe sulfate attack. Air-entrainment can also increase a concrete's resistance to chemical attack.

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 1 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 of 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 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 for 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 trans-

port and placing of concrete. Because the distribution of particles is not uniform in a segregated mix, the concrete is weaker.

Shrinkage occurs in concrete in two major ways: plastic shrinkage and drying shrinkage. Plastic shrinkage is the contraction of the cement past while it is still in a "plastic" state, before setting. This is a normal effect of hydration, but 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 slowly evaporates over time from within the concrete, it undergoes drying shrinkages. 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. Move the decimal point one place to the right for a rough estimate of the gallons of water per bag of cement (a bag of cement weight 94 pounds, a gallon of water weighs 8.3 pounds).

Workability refers to the consistency of the concrete mix. It primarily denotes 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.

• **For Type IV.** “Low-heat” cement is only needed in massive pours such as for gravitational dams and nuclear power plants. However, if low heats of hydration are needed for large pours such as heavy retaining walls an abutments, Type II cement can be used. It is especially important to reduce the temperature rise of large pours in hot weather.

Specifying Compressive Strength

Many people judge the overall quality of concrete by its compressive strength. This is not all bad, since compressive strength is a pretty reliable indicator of a concrete’s durability, including its impermeability to moisture and chemicals and its resistance to frost and abrasion. But there’s more to the story.

For one thing, looking only at compressive strength leads to “28-day thinking” which attributes all of a concrete’s properties to its 28-day compressive strength value. Other properties - impermeability, density, resistance to freezing and thawing, and resistance to abrasion - are at least as important as strength, yet are often overlooked.

Not only can one forget that concrete has a life beyond the 28-day test, but new technologies that might improve concrete performance are ignored as well. For example, silica fume has been shown to increase the

impermeability of concrete, but remains extremely expensive and for the most part unheard of (see “Concrete Prices”).

Even the weakest concrete can support the compressive loads commonly found in residential and light-commercial structures. Therefore, 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 generally call for high-strength concrete. Table 2 offers general guidelines for concrete under different exposure conditions.

Cold weather is perhaps the most destructive condition for concrete. Water that has penetrated into exposed concrete freezes and expands. Repeated freeze/thaw cycles impose an enormous internal strain on the brittle concrete. Unable to take it, the concrete begins to scale and spall.

To protect concrete from freeze damage, it is important to make it impervious to water. This is achieved by using a mix that has more cement relative to the amount of water. The cement past of a richer mix creates a denser product that better resists the entry of water and shield the aggregate particles from absorbing water. (Coincidentally, this also yields stronger concrete.)

De-icing salts intensify freeze/thaw



Figure 1. Air entrainment protects concrete from freeze/thaw damage by introducing very small air bubbles (see inset). These cushion against the expansion and contraction of water particles.

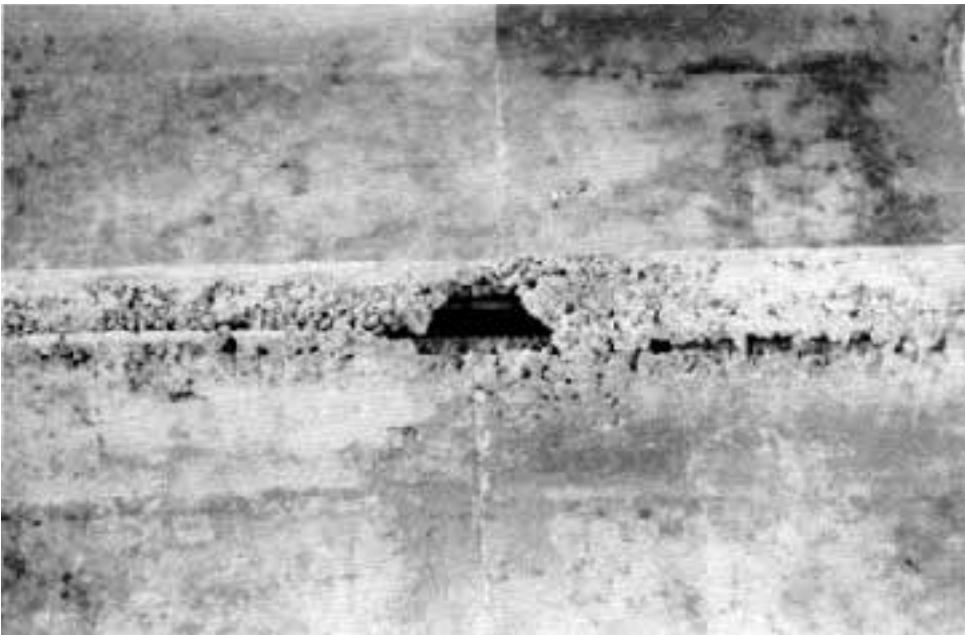


Figure 2. Honeycombing can be caused by poor compacting of fresh concrete or by large aggregate getting stuck between reinforcement. To prevent the latter problem, the coarse aggregate should be much smaller than the smallest space between reinforcement.

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.
Types 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 stems exposed to weather.	3,500-4,000 psi	.45

Concrete Prices

Below are typical prices for ready-mix concrete and various additives from a ready-mix supplier in northern Vermont. Prices in other areas will vary according to delivery zones, local availability of good aggregate, and the demand for a particular product.

Concrete	
2,000 psi	\$64.00/ cu yd
3,000 psi	\$68.00/ cu yd
4,000 psi	\$74.00/ cu yd
5,000 psi	\$78.00/ cu yd
Between November and May there is an additional cost of \$3/cu yd (for preheating cement, aggregate and water).	
Admixtures	
Accelerator	\$1.50 for each percent per cubic yard
Bagged calcium chloride	\$25.00/100 lb
Superplasticizers	\$2.50/cu yd for 2,000 psi and an additional \$1.00 /cu yd for each additional 1,000 psi
Water reducer	Standard for all 4,000 psi and higher, and for all hot-weather concrete
Silica fume	\$25.00/cu yd

damage to concrete by speeding up successive cycles. Salts dissolved in melted ice can also increase the corrosion of steel reinforcement. Where de-icing salts are used, such as on sidewalks and driveways, the need for a stronger, more impermeable concrete is especially high. Garage slabs are included here since water and salts dripping off cars can produce the same adverse effects.

Air-Entrainment

Air-entrainment for concrete was originally developed to improve its resistance to frost attack. It is now recommended for all concrete that is exposed to weather.

The “entrained” air bubbles within the concrete help by providing space to cushion the expansion of freezing water particles (see Figure 1). It might seem that air-entrainment would also make concrete more porous and vulnerable to water penetration. However, because air-entrainment also reduces segregation and bleeding, and improves work-ability, it permits a lower water/cement ratio. The net result is a stronger, more impermeable product.

Almost every yard of concrete that goes out of a batching plant today is air-entrained. Occasionally, however, a finisher will request concrete without air-entrainment. Though air-entrainment may make concrete easier to move around, it creates a “rubbery” texture that makes it more difficult to smooth out. For interior slabs, concrete can be specified without air — entrainment, but it is imperative for all exterior work.

Specifying Aggregate

Aggregate includes both sand and

gravel. In concrete, aggregate functions as a dense mass to restrain the forces placed upon the concrete structure. Without suitable aggregate, concrete tends to gradually deform 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 choosing “lightweight” or “heavyweight” aggregate (see Glossary) there are not a lot of choices for the contractor. Since rock is heavy to transport, a ready-mix supplier is limited by the type of rock that is available locally. Rock types used for concrete aggregate are carefully standardized by the ASTM Standard C-33. Chances are your local batcher will conform to these standards. If aggregate must be shipped into your area, this will be reflected in higher concrete prices.

Different sizes of aggregate are mixed (graded) to provide a full range of particle sizes. Different sizes are needed to fill the voids within the concrete. The fewer voids in concrete the denser it will be. ASTM Standard C-33 provides for a range of particle sizes by designating different sieve sizes for sorting aggregate. These range in number from 3 1/2 to 400 for fine aggregate and from 1/4 to 4 inches for coarse aggregate.

To eliminate honeycombing in reinforced concrete, it is best to specify the largest coarse aggregate you can safely use (see Figure 2). The American concrete Institute (ACI) recommends that for walls, the largest aggregate size should be no more than one-fifth the thickness 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 section only to water/cement ratio is determining the ultimate strength of concrete. Only about 3 1/2 gallons of water are needed to fully hydrate a sack of cement (this corresponds to a water/cement ratio of .31 - compare to Table 2). The remaining water serves only to make a mix workable—that is, one that can be well compacted.

To eliminate honeycombing, ACI recommends that for walls the largest aggregate should be no more than one fifth the thickness of the thinnest section between reinforcing members.

Slump is the measure of workability, defined as the vertical distance a molded mass of fresh concrete will fall when the mold is removed (see Figure 3). 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 4). Some areas may be inaccessible, such as the spread footings for piers, which are often 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 with-

out simply adding water, which reduces the strength of the concrete. To accomplish this, we often 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).

To produce flowing concrete (with slumps upwards of 7 inches), superplasticizers can be specified. Most superplasticizers also retard the setting time of concrete. If superplasticizers concrete is needed in cool weather, a sulfonated-melamine-formaldehyde (SMF-based) superplasticizers is usually called for. SMF-based admixtures allow for a very low water/cement ratio, which in conjunction with the admixture, can actually exhibit a slight accelerating effect.

Water reducers and retarders often have the same chemical base (see Table 2), but serve different purposes. Like superplasticizers, water-reducers are used to produce a more workable concrete without adding water. Most high-strength concretes use a 5-inch slump and depend on a water-reducer for workability.

Retarding admixtures are called for in warm weather when temperatures would otherwise accelerate to setting times.

Accelerators are called for in cold weather to speed the setting tie and increase the rate of strength development. This reduces the time that the concrete needs protection with covers and artificial heat. The most common accelerator used is calcium chloride, but it is to be used with caution since it can corrode steel reinforcement. Building codes restrict the amounts of calcium chloride in reinforced concrete and forbid it in concrete containing electrical conduit.

Calcium chloride also improves the

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 and strength development (primarily used in cold weather operations)
Retarder	Gypsum powder Sugar* Lignosulphate Hydroxycarbolic acid Lignosulfate	To reduce the setting time (primarily used in hot weather)
Water-reducer/ plasticizer	Hydroxycarbolic acid Lignosulfate	To produce a more workable mix
Superplasticizers	Sulfonated melamine formaldehyde (SMF) Sulfonated naphthlene formaldehyde (SNF) Modified lignosulfate (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.

workability of concrete and, for this reason, many finishers like to use it in all of their concrete. However, it should never be used in excess of 2 lbs/bag of cement. Excessive use of calcium chloride can lead to severe shrinkage cracking and loss of strength. If you don't need it, it's better not to use it.

Non-chloride accelerators are gaining popularity for their non-corrosive properties. In the past they were generally considered too expensive. But because they do not corrode steel storage containers, many ready-mix suppliers now prefer to supply them at a minimal cost. Non-chloride accelerators are a bit less effective than calcium chloride but this is usually not a problem. For example, 2-percent calcium chloride accelerates the setting time of portland cement by 125 minutes, versus about 100 minutes for 2-percent calcium formate.

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.

Water-reducers are added with the water to provide the most rapid dispersion into the mix. They are added in amount of about 1 to 5 percent by weight. Superplasticizers are added in amounts of about 1 to 3 percent by weight and some adjustments are made in the portions of cement and aggregate to avoid segregation. Calcium chloride should always be added to the water; an undiluted solution should never come in direct contact with the cement. Some finishers prefer to add bagged calcium chloride to the truck just before it is discharged.

Air entraining agents are either pre-mixed with the cement or added to the sand. In these matters, the expertise of a ready-mix supplier should be relied upon. It is in his best interest to use admixtures correctly since the quality of your product, and his depends on it.

A Good Use for Ash

Mineral admixtures or pozzolans are finely ground mineral substances which, in the presence of water, react with calcium hydroxide (the primary ingredient of cement) to form compounds with cement-like properties. Pozzolans include industrial by-products 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, diatomaceous earth, and calcined clay.

The industrial by-product 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. As a result, new means of disposal were sought, including "dumping these materials into concrete. But the effects are not all bad. For one thing, the materials serve as a partial replacement for concrete, which saves both money and resources. In additions, they have been found to improve the quality of the concrete

Concrete made with pozzolans develop strength very slowly, and must be allowed to cure for long periods of time. Yet the final strength is in most cases higher than usual. This slow development of strength corresponds to a small amount of heat buildup, which helps to eliminate shrinkage cracking in large pours. Pozzolans are also finer than the finest sand, so they fill in the smallest voids between particles of sand. This creates an extremely dense product that is stronger and more impermeable.

A great deal of high-strength concrete (6,000 psi or higher) is made with pozzolans. This is especially true of silica fume whose particles are so small it cannot be bagged. Concrete using silica fume has reached 19,000 psi. while these strengths are not needed in light construction, this points the way towards new concrete technologies that will undoubtedly affect all builders in the future.

It becomes increasingly important to keep up with new developments in concrete technology. In addition to the common use of admixtures and pozzolans, even the cement itself is changing. For example, new cements are now being developed that can eliminate shrinkage cracking by actually expanding 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." ■

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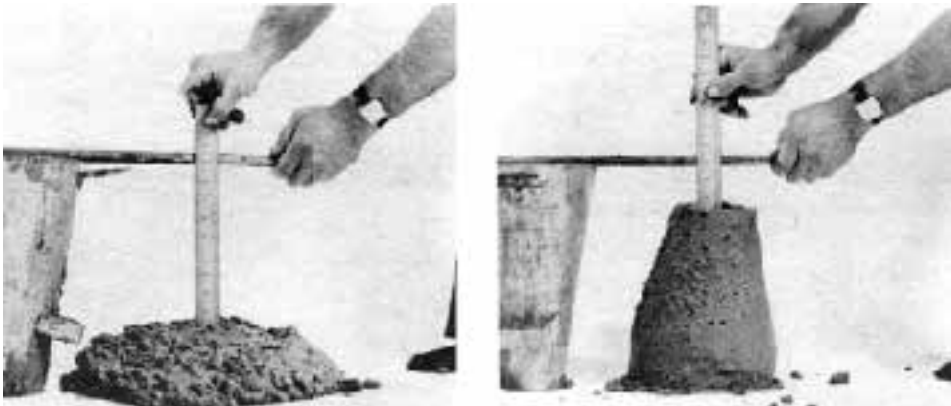


Figure 3. A slump test measures the workability of fresh concrete. To increase the slump without weakening the mix, use a water reducer or superplasticizer.

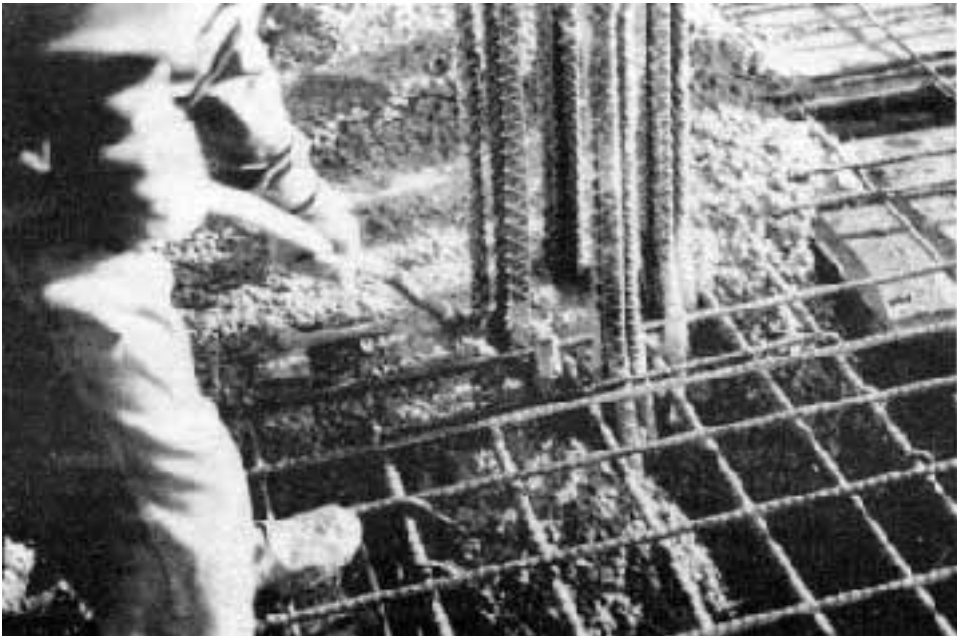


Figure 4. Heavy reinforcement can make it difficult to adequately compact the fresh concrete. A high-slump mix, often achieved with superplasticizers, can help.