Special concretes

A selection of the most important special choices of today

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For the reader who needs only a general acquaintance with the most important special concretes, this article is meant to provide an adequate treatment. Others may also find it a useful introduction. The properties and uses of many special concretes are discussed in somewhat greater detail in the subsequent articles published in this issue.

As recently as the early 1940s concrete was still a fairly simple material. No one expected too much of it. It was useful for foundations, floor slabs, driveways, sidewalks and streets. Its limitations for areas subject to weathering, particularly freezing and thawing, were all too apparent.

Only the most daring and innovative architects considered concrete for walls that extended more than 6 inches[1]* above grade. Its appearance was not expected to be attractive. Concrete was thought to be more appropriate for concealed work, basements, and storage areas where people would not expect to be aesthetically pleased.

The basic ingredients were cement, sand, stone or gravel and enough water to get it into place. It was well recognized that the cement was the active and most important material and that some water was necessary to hydrate the cement and make it set, harden and gain strength. Somewhat earlier (1914), Duff Abrams had established the fact that strength and other properties of concrete were inversely proportional to the quantity of water mixed with the cement.

Fine and coarse aggregates were identified as inert materials used primarily to provide bulk and reduce the cost of a given volume of concrete. Grading and other properties of the aggregates were of no consequence as long as the resulting mixture could be placed and, where necessary, finished.

Quality of concrete for a specific job was usually indicated by a recipe for the mix such as the number of parts of aggregate to be used for each part of cement along with a water-cement ratio stating the maximum quantity of water to be used per part of cement (usually as gallons per sack). In some cases the desired quality was implied by stating the minimum quantity of cement to be used in a cubic yard of concrete. In order to leave nothing to chance, the more conservative specifiers included everything except the age of the man operating the mixer.

Forming was also relatively simple. Any available lumber that was strong enough to resist the pressure of the plastic concrete was satisfactory as long as a wall was reasonably straight or a slab was reasonably level. Dimensional and surface tolerances were only applied on the more sophisticated jobs. Wall forms that were not tight and allowed some leakage of mortar presented no problem since appearance was not a factor on most work.

Handling of the concrete from the mixer to its final resting place was often more muscular than scientific, a strong back and a wheelbarrow being two of the common needs on engineered jobs. When inspection was not involved or was lax, chutes of the length necessary to reach from point A to point B and concrete that would flow down the chutes and reach point B and beyond were equally common. Elevators or cranes were employed when concrete was needed above ground level.

Job-mixed concrete was very much in vogue. The ready mixed concrete industry did not hold its first annual convention until 1930. For the most part, the participants were more interested in the trucking aspect of their operation than in what they were delivering. The major advantages to the contractor were that he did not have to stockpile materials at the jobsite and that the concrete came to him in batches of 2 or 3 cubic yards[2] instead of the ½ or 1 cubic yard[3] he could produce in his own mixer.

* Superscript numbers refer to metric equivalents listed with this article.

The quantities used in batching the materials were the same the contractor would have employed if he mixed his own. The formula was one specified by the architect or engineer or one that the contractor had found suited to his needs. There was a good possibility that the concrete was a little more uniform from batch to batch since the materials were more likely to be batched by weight rather than by rough volume.

Little was known about cement chemistry or the possible interaction of cement with the aggregates. The shortcomings of concrete such as cracking or vulnerability to damage by weathering were simply accepted as facts that could not be altered and concrete was therefore used only where these deficiencies could be tolerated.

Against this background, today's use of concrete is surprising. Instead of the former height limit of 6 inches1 above grade, we now have handsome concrete buildings soaring to heights well over 800 feet.[4] Rather than the previously accepted limit of about 3000 psi,[5] we are now working routinely with strengths of 5000, 7500, 9000 and even 12,000 psi.[6] Whereas we previously restricted the use of concrete to areas protected from the weather, we now place it where it will be exposed to severe weathering, freezing and thawing, and the liberal use of deicing salts.

Concrete has become a truly universal building medium, has demonstrated a versatility possessed by no other material, and has the added advantage of being manufactured from components that are, for the most part, available locally. Only in cases of extremely heavy demand has it been necessary to import cement or ship it great distances across country.

This great change in the performance and acceptance of concrete was due to the efforts of a number of organizations and individuals who were not willing to take the apparent limitations of concrete for granted. Some of the improvements were the result of accidental discoveries while others required long and diligent research into the chemical and physical properties of both cement and aggregates. As the benefits of this added knowledge were demonstrated under job conditions, the viability of concrete as a multipurpose construction and paving material was proven.

Credit is also due to the handful of designers, architects, and engineers who first recognized the potential of concrete as both a structural and architectural material. No longer are concrete surfaces hidden from view by some type of covering, plaster, paint or sheathing or confined to unfrequented areas. The ability of concrete to reproduce faithfully any texture or sculptured detail conceived by the designer is evident on every hand. Many of the beautiful modern structures throughout the world could not have been built with any other material.

Most of the faults that were once accepted as inevitable have been either eliminated or brought under tight control. Concrete production is now a reasonably precise manufacturing operation subject only to the variations that may exist in the raw materials; these, in turn, are now more carefully produced and closely inspected than was once considered possible. It is now common practice to specify end performance rather than provide a recipe for the ingredients. The average concrete producer knows his materials and is competent to make any adjustments necessary to provide whatever characteristic is needed on the job.

Handling of concrete from point of delivery to point of placement has kept pace with other developments and relies very little on back muscles. Pumps or conveyors are employed to move large quantities of concrete from the mixer to the forms with very little change in the consistency or homogeneity of the mix. Relatively stiff mixes can be transported and placed with little difficulty. Compaction against form faces or around intricate reinforcement is accomplished easily with high frequency vibrators.

Recognition of the role played by the aggregates was an important step in the direction of improving both the appearance and the strength of concrete. The modern concrete mixture is based on the physical properties of the aggregates as well as any possible chemical action either beneficial or adverse. Alkali-silica reaction, once a deterrent to widespread use of concrete in many areas, is now controlled by limiting the amount of alkali in the concrete, either by use of a low alkali cement or by modifying the quantity of cement in a volume of concrete.

By proportioning concrete on the basis of physical analysis of both the fine and coarse aggregates, the amount of fine aggregate or sand is now determined as that which will provide adequate workability and a minimum of voids in the aggregate system. Considerable work has been done on the subject of proportioning and refinements are still being made to further improve both appearance and serviceability of concrete structures.

One contribution to the quality and usefulness of modern concrete was made when mineral and chemical admixtures were introduced to the industry. These materials, used properly, provide benefits that would be unattainable without them. Air entrainment is an outstanding example. The ability of concrete to withstand weathering has been greatly enhanced by introducing minute, discrete bubbles of air into the mix. Combined with strengths in the range of 4000 to 5000 psi,[7] the concrete is also resistant to the effects of freeze-thaw and deicing salts.

Fly ash and natural pozzolans help to combat the problem of heat of hydration in massive structures by reducing the amount of cement necessary to secure the required strength. They can also be used to advantage where there is a potential alkali-silica reaction. With these materials it is possible to secure very high strength concrete without excessively high cement contents.

Much of the expanded use of concrete as a structural and architectural material can be attributed to the development of chemical admixtures. Many of these have the ability to reduce mixing water, control the set of concrete and greatly increase strength. Almost any property that is desired in the plastic state of concrete can be obtained without any sacrifice in the quality of the hardened concrete, and often with substantial improvements in hardened qualities.

Slower setting concrete in hot weather, faster setting in cold weather, accelerated early strengths to permit earlier form removal, flowable concrete with the amount of water usually associated with very stiff mixes, good response to vibration, and lower handling and finishing costs are some of the features that appeal to the contractor. Uniformly higher strengths, better appearance and lower maintenance costs appeal to the architect, engineer and owner.

By understanding the role played by the basic ingredients and by proper selection and application of the available admixtures, the performance of concrete can be adapted to a wide number of special uses. Durable concrete for pavements and other exterior uses, very high strength concrete for columns and load bearing walls in high-rise structures, concrete to be transported and placed by pumps or conveyors, concrete for massive structures or thin overlays, pneumatically placed concrete, pre-tensioned and post-tensioned slabs, beams and other structural elements, lightweight concrete and heavyweight concrete, are all within the capability of the modern technologist.

Special concretes can solve special problems

Much of what has been discussed so far is the adaptability of ordinary concrete to a wide variety of end uses. The discussion has also touched briefly on several special concretes. Designers and contractors often come across problems which call for special solutions involving concrete. A special concrete—a concrete made with special ingredients or by a special process—may be ideally suited to the need. The remainder of this article is devoted to some of the broad possibilities of special concretes. Brief descriptions are given so the reader can be better prepared to explore them in depth when the unusual situations come up.

Obtainability of special concretes

Your local ready mixed concrete supplier can usually be of assistance when you need special concretes but don't expect enthusiasm from him in every case, even though our immediate focus is on concretes that ordinarily can be batched, mixed and delivered by a ready mixed concrete plant. Also covered are some concretes for which the ready mix plant provides some of the ingredients and the contractor adds more at the jobsite. After you have studied your problem and the possible solution, put yourself in the shoes of your ready mix supplier and see if servicing your request will make business sense for him. Besides the natural desire to satisfy a customer, he must have the know-how, personnel and facilities to handle the order. If the application represents a sizable order or if it can lead to new business, you'll get a better reception. Recognize the liability exposure too. Anyone who has been around the concrete business very long knows that Murphy's Law is particularly applicable to first-time projects. The ready mix producer's phone will probably ring first if something doesn't turn out as expected. To get over the hurdles successfully consider taking these steps:

- Make certain that both you and the supplier learn as much as you can about the special concrete for your project from the ACI Committee Reports cited here, from other publications and from suppliers of proprietary products when applicable.

- Make good communication one of your main goals. Have advance meetings with the concrete supplier, the proprietary product vendor and any special contractors that may be involved.

- Try out the concrete or the process first on a limited scale to identify the problems before tackling the full job.

- Make sure that your job has assigned to it the best equipment available. Clean drums with new mixer blades can substantially improve most special concretes.

When the parties involved in the project are not experienced with the concrete or process involved, it is a good idea to bring in someone who has the know-how. In any event, there is no substitute for an enlightened buyer. The buyer should learn as much as possible from published information and experienced people before the work starts.

High strength concrete

The term "high strength concrete" is obviously a relative term. It is easier to get high strength concrete in some parts of the United States and Canada than in others. For our purposes here, high strength concrete will be defined as concrete that has compressive strength of at least 6000 psi.[8] In regions blessed with good aggregates and good cements, high strength concrete may be produced by entirely conventional methods, but to achieve 9000-psi[9] concrete or stronger normally requires a special mix with the closest attention to detail for all steps along the line.

First, why use high strength concrete? The primary applications are for compression members such as the interior columns or shear walls or high-rise buildings. There are other applications but the cost-benefit ratio should be checked first. Although high strength concrete improves the performance of flexural members it does not increase flexural capacity very much and the extra cost often cannot be justified. Compression members are not normally loaded fully for at least 90 days so it is permissible to specify 56-day or 90-day compressive strengths rather than the normal 28-day value. This is important because it may be more practical to obtain high strength at later ages with cements that continue to gain strength over a 90-day period and to use some fly ash, which takes time to assist in strength development.

A competent concrete laboratory will be needed to design the high strength concrete mix and test the concrete at the jobsite. ACI 211.1-77 (Reference 1) can be used as a basis for design but modifications may be necessary to achieve concrete in the range of 8000 psi[10] and above. Admixtures are required, sometimes in dosages considerably higher than normally used. In selecting the type and amount of admixture, explore setting time, workability, water reduction, strength and time of addition (Reference 2).

Flowing concrete

Flowing concrete is the name sometimes given to concrete dosed with high range water reducers (superplasticizers). Flowing concrete solves a number of problems because it provides high slump for easy placement without the strength reduction and high shrinkage which would otherwise be encountered by simply adding water. When high range water reducers are added to a 2-inch slump[11] concrete, the mix can become so fluid it is impossible to move with a shovel. At normal temperatures, the mix will be back to a 2-inch slump in 40 to 60 minutes. Thus the concrete has the strength of a low water-cement ratio mix but the fluidity of a high water content batch. Another unique characteristic of superplasticized concrete is that the easy flow is accomplished without segregation if the slump doesn't get over 10 inches.[12]

Flowing concrete is obviously a benefit to poured wall contractors and in applications where there is high congestion of reinforcing steel or other narrow constrictions. It is also apparent that the cement content could be reduced to achieve a higher strength at a given slump with superplasticizers. It is possible to get as good or better results with two 94-pound bags less cement per cubic yard[13] with superplasticizers. Because the high range water reducers aren't cheap, there could be a trade off with the cement savings, and it is always wise to check the economics carefully.

At the present time there are about ten superplasticizers available, but even so your local concrete supplier may not be ready to furnish flowing concrete. It takes some laboratory study to arrive at a mix that provides compatibility of a particular high range water reducer with available cements and aggregates. Then there is the timing problem and getting the man on the job acquainted with the unusual characteristics of flowing concrete. If the mix stiffens up during the pour, it can be re-dosed, but clearly this is expensive.

One way to solve the problem is to add the superplasticizer to the mix at the jobsite. This minimizes the problem with timing but the mix must be designed for the admixture. Depending on the application, the mix may require adjustments in the ratio of coarse aggregate to fine aggregate. Get advice from the admixture supplier and the concrete supplier or a concrete testing laboratory before proceeding with jobsite applications.

The best way to add the superplasticizer to a truck mixer is through a 12-foot-long[14] plastic tube which has a cap on the end and perforations in the last 4 feet.[15] The tube is inserted in the drum while it is not rotating, liquid admixture is pumped into the tube as the mixer is turned on, and the tube is slowly withdrawn. The mixer should be run for about 60 to 100 revolutions after the addition. Some admixture vendors will send a truck with the tube and pumping equipment to the job. If you must dump the superplasticizer into the mixer with a pail, recognize that it takes time for the fluid to get all through the mix; allow at least one minute of mixing time per cubic yard.[16] For more on superplasticized concrete see References 3 and 4.

Special aggregate concrete

To achieve good results in exposed aggregate concrete, the mix should be designed for the purpose. The aggregate should have attractive color and texture characteristics when exposed. In wall applications, the aggregate should be free of ferrous pieces so that rust streaks do not appear later. The aggregate should be free of chert particles which will pop out during freezing weather.

Better results in texture uniformity can usually be achieved by gap grading. As the name implies, in gap grading the middle size aggregate fraction is eliminated or reduced so that the coarse particles dominate when the cement paste is exposed on the surface.

The regular aggregates available locally may not have the desired aesthetic appeal for your project. Usually attractive gravels or crushed stones can be obtained within truck hauling distance. The local concrete plant may not be able to accommodate the special aggregate easily because of limited batch plant bin capacity or outside storage space. If the job is large enough, it may be practical to empty a bin for the purpose. The ready mix supplier should make sure the bin is completely empty before charging the new material. Clean trucks are required and the truck should be carefully washed out before each load. If a central mixer is used, it too must be washed out before each special aggregate concrete batch.

Special aggregates are also available in cloth bags. This may be the appropriate way to handle small jobs. See if your ready mix supplier can weigh out small batches of special aggregate concrete for your exposed application. If not, you may have to mix the concrete at the site or have sand cement grout delivered by transit mixer and add the coarse aggregate at the jobsite with your own portable weigh batching equipment.

Exposed aggregate flatwork can be achieved by waiting for the proper time to scrub off the top coating of cement paste to make the coarse particles visible. To expose the aggregate in vertically cast walls the forms are normally coated with a chemical retarder. Special retarders are available to provide a deep, medium or shallow etch. In tilt-up panel construction a more uniform appearance of exposed aggregate can be achieved by using a retarder on the cast-down face. The other way to do it is to expose the top surface as in patio work. For more information on exposed aggregate concrete for jobsite-precast panels see Reference 5.

Fly ash concrete

In recent years there has been a growing interest in fly ash for concrete because of cement shortages and the abundance of fly ash. Fly ash is less expensive than cement because it is a waste product from power plants burning pulverized coal. Fly is captured flue dust that looks like tiny glass beads under a microscope. The material is gray in color, very fine grained and resembles cement in appearance. Fly ash is not a cementitious material in its own right and can only partially replace portland cement. Silica, aluminum oxide and iron oxide in the fly ash combine with lime from cement hydration to form strong cementing compounds, principally calcium silicates.

Fly ash can be useful in making high strength concrete (8000 to 10,000 psi[17]) if the strength is measured at later ages (56 or 90 days). The spherical shape of the fly ash particles gives better workability to the mix by providing a kind of ball-bearing action. Fly ash concrete is also more resistant than regular portland cement concrete to attack from sulfates in seawater or in high sulfate soils.

If your concrete will be subjected to freeze-thaw cycles, check out the compatibility of the fly ash with the air entraining agent. Fly ash contains some carbon which may have a deleterious effect on the air entraining agent. Measure the air content and add more agent to get the desired level.

The amount of fly ash replacement of portland cement varies with the mix design but in a typical case 70 pounds[18] of cement is replaced with 100 pounds[19] of fly ash per cubic yard. At the same time it may be possible to reduce the water content about 2 gallons per cubic yard[20] to achieve a workability similar to the regular portland cement mix. Fly ash concrete needs longer curing to develop its full strength potential.

For routine projects the benefits of fly ash concrete to the contractor and owner are marginal unless there is a cost reduction. The concrete supplier needs to be equipped with extra silos to handle fly ash if he is to offer fly-ash concrete for sale regularly. More information is available in Reference 6, where fly ash is treated as a finely divided pozzolanic mineral admixture.

Structural lightweight concrete

Structural lightweight aggregates (expanded shales, clays, slates or slags) have been around for a long time but use has diminished because the cost of fuel has forced many of the aggregate producers out of business. Structural lightweight concrete commands a premium price, but since it is 15 to 30 percent lighter than normal weight concrete, this difference can offer important savings in foundation costs for high-rise structures.

There are many applications for which a 100-pound-per-cubic-foot[21] structural concrete would be useful. Concrete in the 90- to 105-pound-per-cubic-foot[22] range requires lightweight fine aggregate as well as coarse. When natural sand is used with lightweight coarse aggregate, strengths of 5000 to 7000 psi[23] can be obtained but the weight runs from 115 to 125 pounds per cubic foot.[24]

The ready mix producer needs extra bins and outside storage to handle lightweight aggregates. He also needs a system for wetting the aggregate in storage. Since mix design can also be tricky, all of these details should be worked out in advance. A special mix may be required if you plan to pump lightweight concrete. Presoaking of the coarse aggregate ahead of mixing is often required. See References 7 and 8.

Shrinkage compensating concrete

In recent years there has been a reduction in the number of cement companies offering the expansive cement used in shrinkage-compensating concrete. Check with your concrete supplier first to see if he can get the cement and handle it at his facility.

When an ordinary concrete pavement, floor slab or structural member is restrained either by subgrade friction or other portions of the structure, tensile stresses develop that often exceed the tensile strength of the concrete. If shrinkage-compensating concrete is used, the concrete will increase in volume after setting and during hardening. When properly restrained by reinforcement or other features of the structure, compressive stresses are induced in the concrete. Subsequently the drying shrinkage merely relieves the compressive stress caused by the expansion.

Shrinkage-compensating concrete is not a cure-all for concrete cracking. Follow the recommendations in Reference 9 for joint details, reinforcement requirements, mix proportioning, placing and curing. Curing is particularly important because the expansive cement needs lots of water for ettringite formation, which causes the expansion. Ponding, continuous sprinkling and wet coverings are more effective than spray-on membranes. Curing should continue for at least 7 days.

Colored concrete

A good result with colored concrete requires preplanning and attention to detail during execution. Color can be given to concrete by integral mixing or by a surface application. The former is more expensive but is generally more successful because it is not as dependent on craft skill and the weather. The pigment can add substantially to the cost of concrete.

Table I lists pigments used for coloring concrete. The additional rate depends upon the pigment and the de-

TABLE I. PIGMENTS USED TO ACHIEVE CEMENT COLORS (from Reference 8)	
Shades of color	**Pigment**
Gray to black	Black iron oxide Mineral black Carbon black
Blue	Ultramarine blue Phthalocyanine blue
Bright red to deep red	Red iron oxide
Brown	Brown iron oxide Raw and burnt umber
Ivory, cream or buff	Yellow iron oxide
Green	Chromium oxide Phthalocyanine green
White	Titanium dioxide

sired color but it should not exceed 10 percent by weight of cement. Normally the dosage is about 6 pounds per 94-pound bag.[25] Follow the pigment manufacturer's recommendations and other detailed information given in Reference 7 concerning color fastness in sunlight and chemical stability in the presence of the concrete alkalis. A clean mixer is essential for every batch. The mixer must be thoroughly washed out at the start of the job and before every batch.

Probably the most practical way to add color to concrete is to weigh out the pigment for each truckload and place the material in paper bags. If a partial truckload is anticipated, batch out the pigment so there is a bag for each cubic yard or part of a cubic yard.[26] The pigment can be added to the truck mixer by charging it with the required number of bags and waiting until the color is thoroughly mixed in. As with other job-applied admixtures, allow at least one minute per cubic yard16 for mixing—over 100 revolutions usually.

It has been found difficult to get strong blue or green colors. To get the right shade of the lighter colors—buff, cream, ivory—may require a white cement or a light colored gray cement. Efflorescence may make colors appear to be faded. Try out a batch or two of the pigmented concrete before committing it to an important project. Color can also be achieved by using colored admixtures, stains, or colored cements (see Reference 11). Several manufacturers specialize in coloring materials for concrete including pigments, admixtures and stains.

Dampproofed concrete

Admixtures for dampproofing slabs include soaps, butyl stearate and special petroleum products. There is considerable doubt about the need for or effectiveness of these admixtures. If a floor slab is made with good concrete, that is, if it has a water-cement ratio not over 0.6 and has been properly cured, the inclusion of dampproofing agents will probably not result in appreciable improvement. To keep water from coming

TABLE II. HEAVY AGGREGATE SOURCES AND SPECIFIC GRAVITIES

Heavy aggregate	Source	Specific gravity	Approximate concrete unit weight: Pounds per cubic foot	Approximate concrete unit weight: Kilograms per cubic meter
Ilmenite (iron ore)	Quebec	4.5	215 - 240	3440 - 3840
Magnetite (iron ore)	Nevada, Wyoming, Montana	4.2 - 4.8	215 - 240	3440 - 3840
Barite (barium sulfate)	Tennessee, Nevada	4.2 - 4.3	205 - 225	3280 - 3600
Limonite	Utah, Michigan	3.4 - 3.8	180 - 195	2860 - 3120
Steel aggregate	Punchings, sheared bars	6.5 - 7.8	310 - 350	4970 - 5160
Iron shot	Cold-chilled shot	7.5	310 - 350	4970 - 5610

through floor slabs it is better to rely on strong, quality concrete, an unpunctured vapor barrier and a granular base. References 6 and 12 provide further information on the subject.

Heavyweight or high density concrete

Concrete can be mixed and placed normally with densities ranging between 180 and 350 pounds per cubic foot.[27] With ready mixed concrete, it is very difficult to go higher than 270 pounds per cubic foot.[28] Heavyweight concrete is used for radiation shielding, counterweights and other applications where maximum weight is desired in a minimum volume. References 1 and 13 deal with heavy concrete. Table II describes the aggregates that may be used.

In batching and mixing heavyweight concrete care should be taken to avoid overloading the equipment. The capacity of a truck mixer will be reduced 20 to 60 percent with heavyweight concrete. A regular transit mixer can handle only about 2 cubic yards[29] of steel punchings concrete. References 1 and 13 provide assistance for selecting the proportions in the mix. Superplasticizers could be a big help in placing heavyweight concrete.

Steel fiber concrete

There are applications for which concrete with high tensile strength, toughness or fatigue resistance is required. Fiber concrete can be used for pavement overlays, patching, armoring hydraulic structures and mine tunnel linings. With imagination, the designer or contractor will think of a number of problems which could be solved by the isotropic strength properties of steel fiber concrete.

Obviously steel fiber concrete will have numerous steel fibers exposed on the surface which will rust with outside exposure. Although such rusting is only superficially disruptive to the surface, it can detract from the appearance. For most functional applications this is not a problem.

It has sometimes been a trick to mix steel fiber concrete without segregation or balling; this is said not to be a problem with fibers that have a low aspect ratio (ratio of length to diameter). Suppliers of steel fibers can offer recommendations on how to disperse the material with their fiber system. There are a variety of methods for adding fibers to a truck mixer but these typically involve special equipment such as platforms, conveyors, vibrating screeds, and forklifts to handle rotating drums. A meeting among the contractor, the concrete supplier, and the steel fiber vendor would be valuable to work out the most practical approach for any specific job. As with heavyweight concrete, a high range water reducer can make placement of the fiber concrete much easier. Check Reference 10 for more details.

Latex modified concrete

Adding a polymer latex to concrete can improve strength, ductility and durability. The latex is essentially a bonding agent which can be mixed integrally with the concrete and gives it superior adhesive properties. The material shows good freeze-thaw, abrasion and impact resistance which allows it to be used for patching and overlays on bridge and parking decks. Latex modified concrete is usually applied in thin layers, and it is possible to get traffic back on the decks within a few hours.

Air-entraining agents should not be used with latex modified concrete. In fact, antifoaming agents may be needed to prevent excessive air contents. The polymer latex is added to the concrete mix in a water solution during mixing. Proportioning and batching procedures are handled normally.

The latex can be added to the mix at the jobsite as with superplasticizers or pigments. Remember to allow the truck mixer enough time to disperse the admixture through the entire batch. Follow the recommendations of the latex manufacturer for dosage rates appropriate for the job. Proper attention to good curing procedures is a must.

Cellular concrete

Cellular concrete (foam concrete) is produced by discharging a stream of preformed foam into a transit mix load of sand-cement grout or a cement-water slurry. The preformed foam resembles shaving cream or the foam used for firefighting. Most of the foam concentrates are hydrolyzed proteins and are available through proprietary sources. The companies distributing the foam typically license subcontractors, furnishing them with the foam generators, pumps for placing the foam concentrates and technical assistance. With some systems a compressor is required.

The sand-cement grout or neat slurry is a cement-rich mix and the resulting concrete will contain about six 94-pound bags of cement to the cubic yard[30] with a density ranging from 15 to 120 pounds per cubic foot.[31] The heavier densities (100 pounds per cubic foot)[32] are used for toppings on floor systems. The major use in recent years has been over plywood on wood floor systems or over hollow-core precast slabs. The material is also used in light density for roof fills (30 pounds per cubic foot[33]) and thus has good insulating properties. The heavier material is made by shooting foam into the sand-cement grout mix and the lighter concrete is made from the cement slurry.

Cellular concrete can be used as a backfill in or around engineering structures when this is more practical than using soils. It has also been used as a foundation material where the soil is of very poor quality.

Cellular concrete is almost always pumped. In foundation applications, such as sewer backfills, it can be dumped from the truck through a large funnel.

Cellular concrete has high drying shrinkage and cracks are inevitable in insulating floor and roof decks; the cracks are considered unobjectionable. The material should not be left exposed as a wearing surface but must be covered with something. The Cellular Concrete Association recommends that a wet density test be made at least once each hour during placement and that the weight be controlled within 5 percent of that specified.

Selected bibliography

Most of the ACI standards and committee reports are published in the five-part volume ACI Manual of Concrete Practice 1980. The book that contains the document is noted in the reference (Example: Part 2).

(1) ACI 211.1-77, "Recommended Practice for Selecting Proportions for Normal and Heavyweight Concrete." Part 1.

(2) Blick, Ronald L., "Some Factors Influencing High-Strength Concrete," Modern Concrete, April 1973, page 38.

(3) Malhotra, V. M., "Superplasticizers in Concrete," Concrete Construction, March 1978, page 142.

(4) Pinjarkar, S. G., Osborn, A. E. N., Koob, M. J. and Pfeifer, D. W., "Rehabilitation of Parking Decks with Superplasticized Concrete Overlay," Concrete International, March 1980, page 62.

(5) "Jobsite Precast Concrete Panels—Textures, Patterns, and Designs," Portland Cement Association, Publication IS061.03A.

(6) ACI 212.2R-71, "Guide for Use of Admixtures in Concrete." Part 1.

(7) ACI 211.2-69 (Revised 1977), "Recommended Practice for Selecting Proportions for Structural Lightweight Concrete." Part 1.

(8) ACI 304.2R-71, "Placing Concrete by Pumping Methods." Part 2.

(9) ACI 223-77, "Recommended Practice for the Use of Shrinkage-Compensating Concrete." Part 1.

(10) Payne, H. F., Organic Coating Technology, Volume 2, John Wiley & Sons Inc., New York, 1961, 725 pages.

(11) Dabney, Charles, "Comparisons of Concrete Color Methods," Concrete Construction, May 1976, page 204.

(12) "Effectiveness of Concrete Admixtures in Controlling the Transmission of Moisture Through Slabs-on-Ground," Report Number 14, Building Research Advisory Board (National Research Council Publication 596), July 1958.

(13) ACI 304.3R-75, "High Density Concrete: Measuring, Mixing, Transporting and Placing," Part 2.

(14) ACI 544.1R-73, "State-of-the Art Report on Fiber Reinforced Concrete." Part 5.

(15) ACI 523.3R-75, "Guide for Cellular Concretes above 50 pcf, and for Aggregate Concretes above 50 pcf with Compressive Strengths Less than 2500 psi." Part 5.

Metric equivalents

(1) 150 millimeters
(2) 1.5 or 2.3 cubic meters
(3) 0.4 or 0.8 cubic meter
(4) 240 meters
(5) 12 megapascals
(6) 34, 52, 62 and 83 megapascals
(7) 28 to 34 megapascals
(8) 41 megapascals
(9) 62-megapascal
(10) 55 megapascals
(11) 50-millimeter-slump
(12) 250 millimeters
(13) 110 kilograms less per cubic meter
(14) 3.5-meter-long
(15) 1.2 meters
(16) 80 seconds per cubic meter
(17) 55 to 69 megapascals
(18) 40 kilograms per cubic meter
(19) 55 kilograms per cubic meter
(20) about 10 kilograms per cubic meter
(21) 60-kilogram-per-cubic-meter
(22) 53- to 62-kilogram-per-cubic-meter
(23) 34 to 48 megapascals
(24) 68 to 74 kilograms per cubic meter
(25) 6 percent by weight of cement
(26) cubic meter or part of a cubic meter
(27) 2860 and 5610 kilograms per cubic meter
(28) 4320 kilograms per cubic meter
(29) 1.5 cubic meters
(30) 335 kilograms per cubic meter
(31) 240 to 1900 kilograms per cubic meter
(32) 1600 kilograms per cubic meter
(33) 480 kilograms per cubic meter

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