Special cements for special concretes

An introduction to their properties and uses

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A magnesia-phosphate cement is being used to patch a highway. Its rapid-setting and rapid-hardening properties minimize the disruption of traffic.

Special cements are cements that serve some specific function such as altering the setting or hardening behavior of a concrete, producing different colors for architectural effects, imparting superior workability, imparting water retention and plasticity to mortars, resisting the penetration of water in walls or containment vessels or simply reducing the cost of the cementing agent. The following descriptions of special cements deal only with the basic characteristics of the cements and their applications.

Many of the special cements described are basically portland cements, while others are considerably different from portland cement in their chemical composition and their behavior. In all cases, the first rule for using any special cement is to follow the manufacturer's recommendations as closely as possible. Properly used, special cements can serve a variety of specialized requirements. Improper application can result in poor performance and costly repairs.

ASTM specifications cover most types of cement used in construction. In the following descriptions, applicable ASTM specifications are cited where appropriate.

Blended hydraulic cements

The three kinds of blended hydraulic cements available are portland blast-furnace slag cement, portland-pozzolan cement and slag cement; their ASTM designation is C 595.

Portland blast-furnace slag cement is available as Type IS for use in general concrete construction or as Type IS-A where entrained air is desired. If moderate sulfate resistance is specified this is indicated by the addition of the suffix (MS) to the selected type designation. Where moderate heat of hydration is desired, the suffix (MH) is added. Thus a portland blast-furnace slag cement which is air-entraining and has moderate heat of hydration and moderate sulfate resistance would be designated as Type IS-A (MH) (MS).

These cements are produced by blending or intergrinding portland cement and finely granulated blast-furnace slag. The blast-furnace slag content of these cements is between 25 percent and 65 percent of the weight of the cement. They have lower heat of hydration and lower 3- and 7-day cube strengths, although specification requirements are the same for Type I and Type IS cements. Due to the slower hardening behavior, curing time should be increased, especially in cold weather. Concrete made with portland blast-furnace slag cement may have a green-blue tint while curing which might be objectionable. Concrete made with Types IS (MS) and IS-A (MS) will successfully resist attack by seawater and similar materials. Such cements are therefore widely used in marine construction, especially in Europe. They are suitable for use in large masses of concrete because of low heat of hydration but are not recommended for use in prestressed concrete.

Portland-pozzolan cements are specified in four types, designated Types IP, IP-A, P and P-A. The first two are used in general concrete construction; the latter two, which are allowed to have lower strengths, are used in concrete construction where high strengths at early ages are not required. Those with the A designations are the air-entraining counterparts of the other two.

Portland-pozzolan cements are manufactured by intergrinding portland cement clinker with a suitable pozzolan, by blending portland cement or portland blast-furnace slag cement with a pozzolan or by a combination of intergriding and blending. The pozzolan content of these cements is between 15 and 40 percent of the weight of the cement and the difference between Types IP and P is in the amount of pozzolan used. A pozzolan is a siliceous or siliceous-aluminous material that will react chemically in the presence of moisture with calcium hydroxide (which is released during the hydration of portland cement). Fly ash is the most common pozzolan used in portland-pozzolan cements.

Advantages of Types IP and IP-A cements include improved sulfate resistance, improved workability and pumpability, better finishability and reduced heat of hydration. Compressive strengths of Type IP cement concretes are generally lower through 28 days than those of concretes with Type I cement but at 90 and 365 days strengths are comparable. In some cases, portland-pozzolan cement concretes have exhibited higher strengths at ages greater than 28 days than have concretes made with Type I cement. Laboratory studies have indicated that resistance to deicer scaling is somewhat less for air-entrained concretes made with Type IP cements than it is for concretes made with Type I cements. Air-entraining agent requirements are higher for Type IP cements than for Type I cements.

If necessary, Type IP may be designated moderate heat of hydration (MH) or moderate sulfate resistance (MS) while Type P may be designated low heat of hydration (LH) or moderate sulfate resistance (MS). ASTM C 595 gives special strength and heat of hydration requirements for these cements.

Slag cement is a blend of at least 60 percent water-quenched blast-furnace slag and hydrated lime. ASTM C 595 covers two types: S and SA

These cements gain strength very slowly but may be used in massive structures, cemented hydraulic fills in mining operations, and masonry cements. They may also be blended with portland cement in making concrete.

Cements with special setting and hardening properties

Portland cements are manufactured in a way that is meant to provide sufficient working time at ordinary temperatures before initial set and a reasonably rapid gain in strength thereafter. Although there are ways of altering these effects on the job, sometimes it is necessary to use a special cement instead.

Type III cement (actually a portland cement specified in ASTM C 150) has been widely used with or without admixtures for repair work, winter concreting and precasting operations where rapid hardening is desired. It is low in cost, easily available, simple to use and produces reasonably durable concrete when used with an air-entraining admixture. Strength gain of rich, low slump mixtures is rapid in warm weather but may not be sufficient to permit early use of a repaired area if temperatures are below 50 degrees F.[1]* Calcium chloride added at a rate not exceeding 2 percent by weight of the cement, and preferably premixed with water, can be used to partially offset the reduced rate of hardening in cold weather. Other accelerators not containing chlorides are also available for use if corrosion of embedded metals is feared or if specifications do not permit the use of chlorides. Good control of mixing water is necessary to prevent excessive shrinkage and cracking in patches made of Type III cement concretes.

Rapid-setting portland cements have initial setting times much shorter than the standard period of 45 minutes. Final setting times are also short. These cements can be manufactured by altering the chemical composition or fineness of portland cement, or by blending portland cement with high alumina cement. Several proprietary mixtures are available.

Rapid setting can also be produced by adding an accelerating admixture in sufficiently large quantity when mixing concrete made with a Type III cement. As a general rule, strengths of rapid-setting cements are lower than those attainable with cements of normal setting times. However, they can be used to advantage for special applications such as sealing water leaks and in some repair applications.

High alumina cement, sometimes called calcium aluminate cement or aluminous cement, is very different in its composition and in some properties from portland cement, but concreting techniques are similar. It has a very high rate of strength development with as much as 90 percent of its ultimate strength being achieved at the age of 24 hours. This makes it useful in manufacturing precast, prestressed members because prestress can be transferred in less than a day without high-temperature curing. The quick turnaround time for formwork is also an advantage in any precast work. The rapid hardening is not accompanied by rapid setting, and in fact the initial set is generally slower than for portland cements. However, final set follows initial set more rapidly. The setting time of high alumina cement is strongly affected by the addition of portland cement and when either cement constitutes between 20 and 80 percent of the mixture, flash set may occur. Additions of plaster, lime or organic matter can have a similar effect.

Other advantages of high alumina cements include good performance in sulfate-bearing ground and in seawater, good resistance to many forms of dilute acid attack and excellent performance when used with insulating or refractory types of aggregates at temperatures above 1800 ° F.[2]

A major disadvantage of high alumina cement is cost—it may be three times as expensive as ordinary

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

portland cement. In addition, upon exposure to hot and moist conditions, high alumina cement concrete will lose a considerable portion of its strength due to conversion of unstable hexagonal aluminate hydrates to cubic hydrates. Thus it should not be used in structural concrete unless the strength obtained at 24 hours is above 200 percent of the design strength.

A few other differences between high alumina cement concretes and those made with portland cement should be noted. The color is much darker than that of portland cement, although a white variety is manufactured. Concrete mixtures are somewhat harsher to work than those made with portland cement and a slightly higher sand content may be necessary. Loss of water during the first 24 hours after placement must be prevented by wet curing which also reduces the rise in temperature of the concrete due to early hydration. However, prolonged curing is not necessary and may be harmful because the conversion of crystalline form mentioned previously reduces strength. Because of the rapid setting when high alumina and portland cements are combined, it is essential to avoid contamination such as might occur in a bin used for both kinds of cement.

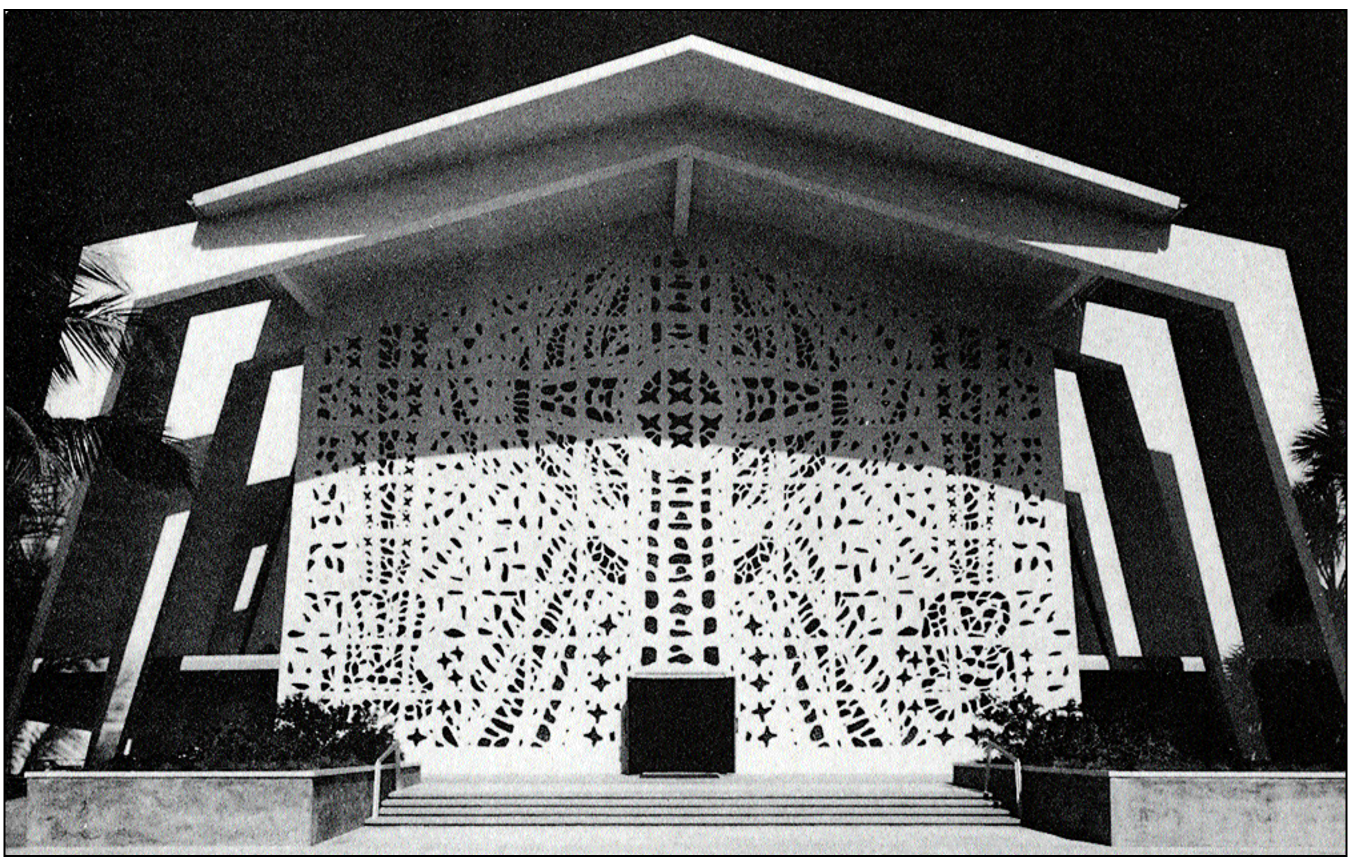
High alumina cements aren't covered by ASTM specifications. They are available in the United States under the brand names Lumnite and Fondu.

Magnesia-phosphate cements are chemical setting materials that set quickly and gain strength very rapidly. They may be used in patching mixtures consisting of a two-component formulation in which the magnesia is supplied in dry form with a measured quantity of liquid phosphate to be added or consisting of a one-component mixture to which water is added. Either must be mixed in relatively small quantities and worked very rapidly because of the rapid setting. The commercial products can be used without aggregate for shallow patching work or can be extended by adding uniform-size aggregate for use in deep patches.

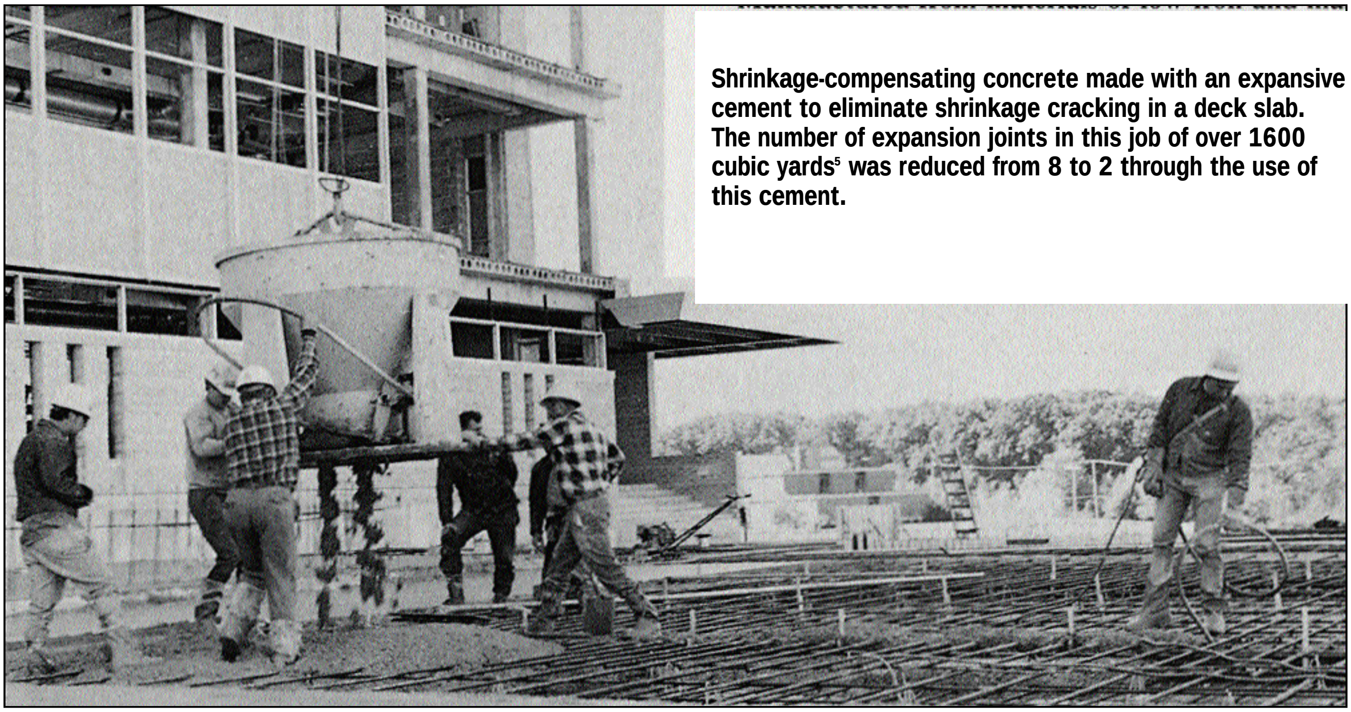
The main uses for magnesia-phosphate material have been in patching, joint repair and full-depth structural repair. The ability of magnesia phosphate cement to gain strength rapidly even under low temperature conditions is useful in minimizing downtime when repairs are made. Bond to other materials is excellent. Air drying is necessary for a proper cure because wet curing will affect the hardening adversely.

Magnesia-phosphate mixtures are expensive, with material costs running $400 or more per cubic yard even with aggregate extenders added. They are not recommended for patches less than ½ inch[3] deep and are not suitable for featheredge patching. Saw-cut edges at the patch boundaries are essential to proper performance.

Oil-well cements of eight classes are described in the American Petroleum Institute Specification for Oil-Well Cements and Cement Additives (API Standard 10 A). These special slow-setting cements were developed for



White cement church building with stained slab glass insets. Second Presbyterian Church, Fort Lauderdale, Florida.



Shrinkage-compensating concrete made with an expansive cement to eliminate shrinkage cracking in a deck slab. The number of expansion joints in this job of over 1600 cubic yards[5] was reduced from 8 to 2 through the use of this cement.

concrete used to seal oil and gas wells and are designed to set and cure at the high temperatures and pressures encountered in oil-well grouting. They may differ in composition from regular portland cement in that the tricalcium aluminate content is low, they are more coarsely ground, and they may contain friction-reducing additives and special retarders to produce a low-viscosity, slow-setting slurry that reduces the amount of pressure required for pumping into place.

Cements with special colors

The earthy, usually gray, tone characteristic of any portland or other hydraulic cement is usually characteristic of the particular sources of raw materials used. To obtain white, buff or other colors may require special materials or special burning.

White Portland cements are manufactured to meet the same requirements of ASTM C 150 as gray cements of Types I, IA, III and IIIA. Their primary use is in cast-in-place or precast, prestressed architectural concrete to create special architectural effects for white, colored or exposed-aggregate surfaces. Additional uses are for terrazzo, stucco and decorative concrete blocks. The inherent beauty and ability to complement variations in texture, pattern and color justify the additional cost, which is about twice as much as that for standard cements.

Manufactured from materials of low iron and manganese content, white cement also has a low content of soluble alkalis. In most other respects its basic chemical composition is the same as that of gray portland cement. It is ground more finely and has a lower range of specific gravity.

White cement is usually chosen for use in mixes for colored concrete walls and other tinted surfaces because it enhances color brightness. There are also colored cements that are made from white cement and pigments. These have good nonstaining properties and uniform color. Alternative methods for coloring concrete made with white cement include the use of colored admixtures, addition of mineral oxide pigments directly to the concrete or use of colored exposed aggregates.

The use of white cements requires careful attention to cleanliness on the jobsite. Mixing and placing equipment, form materials and trowels must be absolutely clean so that form oils or rust from tools or equipment do not cause staining. If possible, smooth surfaces should be avoided with white concrete because differences in texture and color show up markedly. There is also slightly more tendency for white concrete surfaces to craze than there is for gray concrete surfaces. This crazing is much more apparent on smooth surfaces than it is on textured surfaces. On flatwork, surface burns are avoided by troweling while the surface is moist. Curing materials that could cause stains must be avoided. Slabs should be cured with nonstaining waterproofed paper and the paper should be overlapped and sealed at the seams with a nonstaining material.

Buff-colored cements that impart a buff or tan hue to the finished concrete are commercially available. Consistency in color is made possible by a manufacturing process that does not require specially selected raw materials. Buff-colored cements used in structural work must meet the requirements of ASTM C 150 even though that specification does not specifically mention color requirements.

Masonry cements

Masonry cements are covered under ASTM C 91. They may contain one or more of the following materials:

portland cement, portland-pozzolan cement, slag cement or hydraulic lime; and in addition may contain one or more materials such as hydrated lime, limestone, chalk, calcareous shell, talc, slag or clay. Materials are selected for the purpose of imparting workability, plasticity and water retention to masonry mortars. Masonry cements may be used in combination with portland or portland blast-furnace slag cements or as the only cementing agent in mortar for unit masonry. The choice is dependent upon whether property specifications or proportion specifications are used and upon the values for compressive strength and water retention obtained with a particular masonry cement.

Water-repellent cements

Water-repellent cements, sometimes incorrectly called waterproof cements, are portland cements interground with a small portion of a water-repellent material such as calcium stearate. The purpose for using such cements is to reduce water permeability of the mortar or concrete made with them. The use of these cements should not be a substitute for proper control of water and cement content, or adequate curing to produce low permeability concrete.

Expansive cements

These cements are designed to expand initially so that they compensate for the normal shrinkage of the cement paste as drying occurs. ASTM C 845 covers expansive cements and identifies three types, K, M and S, with different expansive ingredients. Type K is a mixture of portland cement, anhydrous tetracalcium trialuminate sulfate, calcium sulfate and uncombined lime. Type M is an interground or blended mixture of portland cement, calcium aluminate cement and calcium sulfate. Type S is a type of portland cement containing a large computed tricalcium aluminate content and interground with more calcium sulfate than usually found in portland cement. Expansion is caused by hydration of the expansive ingredients.

Expansive cements are used in shrinkage-compensating concretes. These concretes find application in concrete structures, especially floors and slabs, where normal drying shrinkage cracking is undesirable. When properly restrained by reinforcement or other means, shrinkage-compensating concretes will expand by an amount about equal to the expected drying shrinkage. Because of the restraint, a compressive stress is induced in the concrete and subsequent drying will reduce this stress rather than cause tensile stresses and cracking to develop.

Usually, a resilient type of restraint of the kind provided by reinforcing bars is necessary to develop shrinkage compensation, although this is not always the case. Use of shrinkage- compensating concrete for post-tensioned slabs with no internal reinforcement has been advocated to eliminate two-step post-tensioning (see CONCRETE CONSTRUCTION, February 1979, page 117). In the usual case, the induced compressive stress depends on the amount of reinforcement as well as the expansion of the concrete.

To ensure adequate expansions and satisfactory results when expansive cements are used, good quality control and onsite supervision are necessary. Expansive cement concretes require more water than normal concretes due to early formation of the expansive phase. Consequently, special care must be taken to thoroughly wet the base or subgrade, prevent plastic shrinkage cracking, avoid placing delays and minimize mixing time, especially at concrete temperatures above 85° F.[4] Moist curing is doubly important because without it failure to achieve desired expansions as well as desired strength will result.

Metric equivalents

(1) 10 degrees C
(2) 980 degrees C
(3) 13-millimeter
(4) 30 degrees C
(5) 1225 cubic meters

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