Stack linings made with calcium aluminate cements do not break down from heat. This special-purpose cement fills the need for a binder which hardens when mixed with water and retains strength after prolonged exposure to furnace heat.

Special purpose cement used in

Calcium aluminate cement concrete

A rapid-hardening material which resists high temperatures and corrosive substances

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Calcium aluminate (CA) cements are similar to the more familiar portland cements in that they both require water for hydration, they both form concretes that set in about the same time, and they both require similar mix designs and placing techniques.

There are, however, important differences between the two cements that should be recognized. First, portland cements are made by reacting limestone and clay to produce calcium silicates, while calcium aluminate cements (also called high-alumina cements) are made by reacting a lime-containing material with an aluminous material to produce calcium aluminates. Second, calcium aluminate cements, when mixed with suitable aggregates, are generally used for special applications where advantage can be taken of their unique properties. Calcium aluminate cements are rarely used for cast-in-place structural work, except for emergency repairs and foundation construction. Some of the purposes for which CA cement concretes may be specified include:

- cold weather work
- resistance to high temperatures
- rapid hardening
- resistance to mild acids and alkalies
- resistance to sulfates, sea water, and pure water

Cold weather concreting

Calcium aluminate cement concrete can be placed at near-freezing temperatures, will harden rapidly under these conditions and give very high strengths within 24 hours, so long as it is protected from freezing prior to initial set. With other types of cement, the hydration process is greatly slowed or stops altogether at low temperatures. The only caution is to keep ice crystals from forming in the concrete until the natural heat development, which occurs a few hours after placing, will prevent freezing. A general rule is to place the concrete under conditions of gradually rising air temperatures rather than falling temperatures.

In addition to being used for concreting in very cold conditions, CA cement concretes are used in cryogenic areas, such as the loading docks of liquid-gas plants, where thermal shock may be a factor.

Resistance to high temperatures

When calcium aluminate cements are mixed with suitable aggregates, they produce refractory concretes (castables) that can be used at very high temperatures, sometimes in excess of 3500 degrees F. Typical applications of the heat-resisting or refractory uses for such concretes include stack linings for power plants (lower temperatures within the refractory range), tunnel kiln cars or linings for petrochemical heaters (intermediate temperatures), and steel furnace linings (highest temperatures).

Rapid hardening

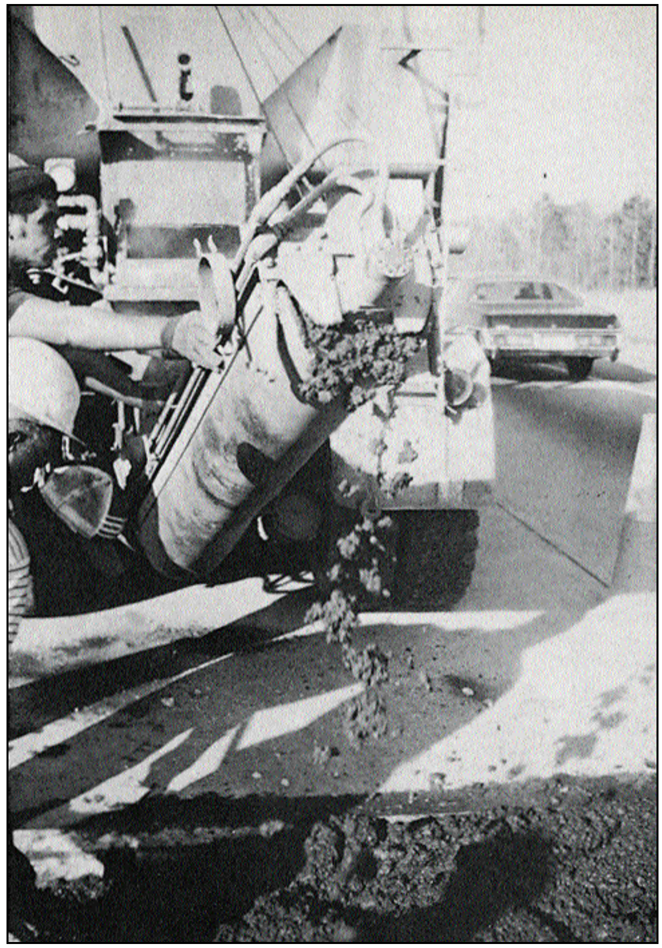
It is important to differentiate between rapid setting and rapid hardening. Calcium aluminate cement concretes are not rapid setting; in fact they may have similar setting times to portland cement concrete. They are, however, rapid hardening; that is, they will develop as much strength in 24 hours as portland cement concrete will achieve in 28 days.

The need for rapid hardening is found whenever downtime is important, and it is necessary to put a concrete lining, floor or highway patch, for example, back in service within a few hours. There are two types of formulation—the normal setting concrete and the ultra-rapid setting concrete. The normal setting concrete (about 2 hours) consists of calcium aluminate cement and an appropriate aggregate such as a siliceous gravel or a limestone. As with regular concretes extremes of temperature will affect the working and setting time. Some CA cement concretes may set later than 2 hours, yet still provide extremely high 1-day compressive strength. The ultra-rapid setting concrete (a few minutes) contains a mixture of calcium aluminate cement and portland cement; some strength is sacrificed to get the early setting action.

Resistance to acids and alkalies

Calcium aluminate cement concretes are not acid proof, but they are resistant to the corrosive effects of certain acids and industrial wastes. They can be used to resist corrosion down to a pH of about 3.5 to 4.0, depending on type of acid, temperature, length of exposure, frequency of washing and other factors. This makes the concretes suitable for use in such corrosive environments as wineries, tanneries, sugar refineries, breweries, bakeries, dairies, fisheries and food processing plants. These concretes are also resistant to alkalies up to a pH of 12, with the exception of alkali hydroxides.

It is of interest to speculate on the future use of calcium aluminate cement concretes in light of the acidic rainfall that is now occurring in many regions of both Canada and the United States. Such rainfall is reported to have a pH below 4.0 and may possibly cause significant deterioration of portland cement concrete.



The rapid hardening of calcium aluminate cement concrete makes it suitable for highway and bridge deck repair. It is being increasingly used for such applications where road or bridge deck can be opened to traffic within a few hours after placing the concrete.

Resistance to sulfates, sea water and pure water

Calcium aluminate cement was originally developed for making concrete that is suitable for exposure to sulfate ground water and sea water. The ground water salts are usually calcium sulfate, magnesium sulfate, and sodium sulfate; in sea water, magnesium sulfate is the principal chemical.

Concretes based on calcium aluminate cements are therefore recommended for the construction of piers and for the lining of sewer pipes. The ability of these concretes to also resist attack by pure water makes them suitable for lining pipes that carry drinking water and industrial waters.

NONREFRACTORY MIXES WITH CA CEMENT

When considering the applications of calcium aluminate cement concretes, it is often convenient to distinguish between those formulations that are designed to withstand heat (refractory concretes) and those that are not. While field mixes for refractory concretes are sometimes made by the end user, it is usually best to purchase premixed materials (castables) from one of many refractory manufacturers. In this way, reliability and consistency are assured.

The guidelines given below should be followed for designing and placing concretes for nonrefractory uses.

Aggregates

Generally the same precautions used in selecting aggregates for portland cement concrete should be followed for nonrefractory calcium aluminate cement concrete. Concrete sand should not contain material finer than 70 mesh. Suitable aggregates include siliceous gravels, limestone, trap rock, diorites and rhyolites. Siliceous sands and gravels are recommended for acid resistance. Granites should not be used because they contain alkalies that react adversely with the cement.

Mix design

Again, the guidelines used for calculating the relative amounts of sand and coarse aggregate for portland cement concrete are generally applicable to calcium aluminate cement concrete. However, the amount of cement required to provide a workable mixture and to give acceptable strengths is normally between seven and nine bags (658 to 846 pounds) per cubic yard of concrete. Concretes exposed to freeze-thaw conditions, or those requiring high strengths, should contain 8 to 9 bags of cement per cubic yard.

Water-cement ratio

The most common mistake made in placing calcium aluminate cement concrete is using too much water. A maximum water-cement ratio of 0.4 (including water in the sand and coarse aggregate) is recommended. For mix designs specifying 8 to 9 bags of cement per cubic yard of concrete, water-cement ratios of 0.35 to 0.37 are not uncommon. A general guideline is that if the concrete can be “poured” rather than placed using vibration, it is probably too wet. Because the water-cement ratio is somewhat lower than for ordinary cast-in-place concrete, adequate compaction may require more than usual vibratory effort.

Mixing and placing

The first precaution here is to use clean tools, aggregates and water. Contamination by lime, plaster, portland cement or recently hardened portland cement concrete can cause a flash set. The mixer should be washed periodically and the wash water thrown away. The concrete can be adequately mixed in about 2 to 5 minutes depending on the volume being mixed. Total mixing time should not exceed 6 to 8 minutes, and the mixture should be placed as quickly as possible and consolidated by mechanical vibration.

Curing

Calcium aluminate cement concretes should be cured for at least 24 hours, using a water spray or fog, ponding, wet burlap or a curing membrane.

When working with calcium aluminate cement concrete for the first time, one must remember that it should be handled much the same way as portland concrete. For satisfactory results, however, two points should be emphasized. First, keep the water-cement ratio below 0.4 and use mechanical vibration to place the concrete. Second, these concretes develop heat much more rapidly than portland cement concrete does, and good curing for 24 hours after placement is mandatory for satisfactory strength gain.

UNDERSTANDING THE CONVERSION PHENOMENON

Finally, no discussion of calcium aluminate cements would be complete without some mention of the failure and collapse of some precast prestressed beams made from calcium aluminate concrete in England in the 70’s. To understand what happened requires a brief description of conversion, a phenomenon associated with all calcium aluminate cements.

Conversion is a process by which the hydrates initially formed in the concrete alter their crystal structure from a metastable to a stable form. This change in crystal structure, the rate of which is dependent on temperature and time, is accompanied by a strength loss. This loss of strength is no problem to the user of calcium aluminate cement concrete provided he designs his mix based on converted and not on unconverted strength. To do this, the total water-cement ratio (including water in aggregates) must not exceed 0.4 and the cement content must be at least 7 bags per cubic yard of concrete.

The entire slab area of a new multimillion-dollar paper plant was recently placed using calcium aluminate cement concrete. This plant came on stream late in 1981 in south Georgia. A total of 158 tons of high alumina cement went into the production of about 450 tons of concrete. This special concrete was used to provide mill floors with resistance to “black liquor,” a highly corrosive sulfate by-product of the pulp-making process.

In the old plant, a similar floor area of conventional concrete had deteriorated down to the reinforcing bars after 7 years of service, whereas the new installation is expected to last 20 years or longer.

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