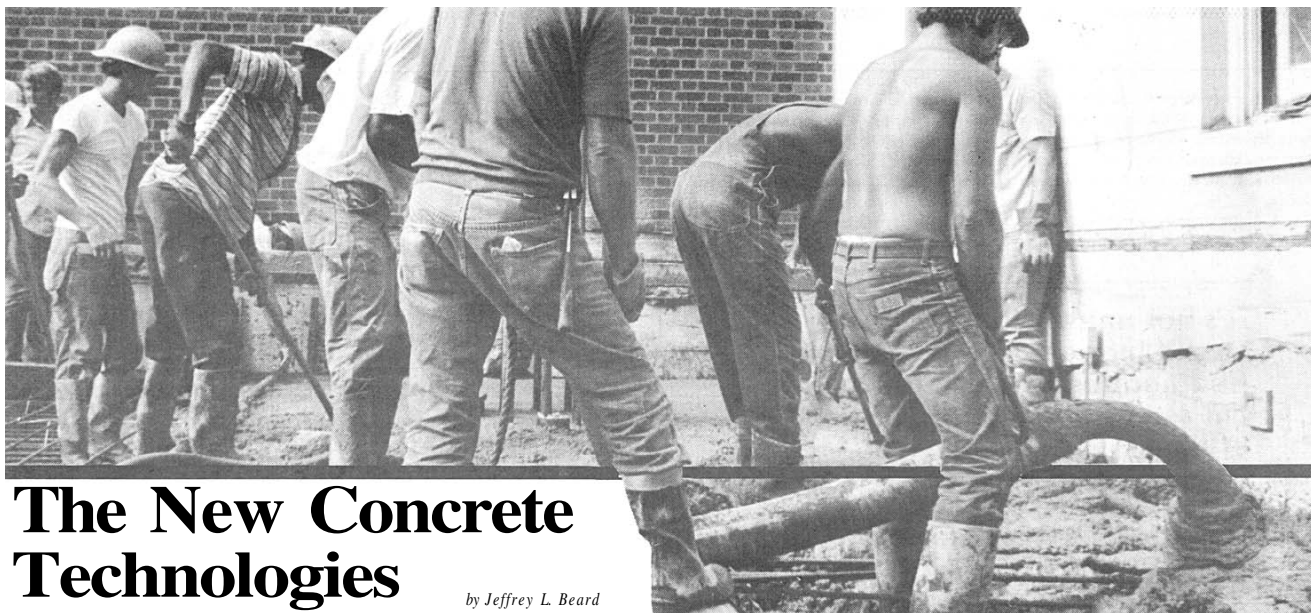




The New Concrete Technologies

by Jeffrey L. Beard

While quarrying limestone on the slopes of Mt. Vesuvius, ancient Roman engineers stumbled upon a naturally occurring cement created by the extreme temperatures and pressures of the volcano. They discovered that the silica-alumina substance, when mixed with limestone and burned, would harden underwater as well as in the air, unlike mortar. They also found that the material was much harder and stronger than ordinary lime mortar.

This material, which contained the essential elements of today's man-made portland cement, changed the character of Roman construction. Initially, columns, arches and vaults were built with masonry facings, then filled internally with the Vesuvian cement. Later, the plasticity and moldability of wet cement was exploited for the construction of new architectural forms: Roman cross vaults and domes.

Concrete construction has undergone significant changes in the 2,000 years since the material was first used. Today's chemical engineers have analyzed the molecular structure and performance characteristics of modern man-made portland cement to determine proper types for a wide variety of construction applications.

Ingredients and Additives: Two Key Variables.

By volume, aggregates are the predominate ingredient in concrete, accounting for roughly 75 percent of the total. Size of aggregate is extremely important because a range of sizes allows the particle mix to be packed closely together.

We are all familiar with the typical aggregates which consist of crushed stone and sand, but increasing use is being made of lightweight aggregates such as expanded mica (vermiculite) and expanded volcanic glass (perlite). One use for low-density concrete mixtures is structural lightweight concrete. To create structural lightweight aggregate, shale particles are heated in an oven until the material becomes plastic in consistency. At that time, small amounts of water occurring naturally within the shale turn to steam and "pop" the particles of aggregate like popcorn.

Concrete made with this aggregate has a density about 80 percent of normal concrete, while retaining most of the strength. Dead loads of structural elements in construction are reduced proportionally when using this mix.

But ingredients other than portland cement and aggregate, such as pozzolans and plasticizers mentioned later in this article, have given concrete added versatility as a construction material.

Blended Cements:

Blended hydraulic cements combine portland cement with industrial by-products. Fly ash, produced in quantity by coal-burning utilities, is enjoying increased use as a binder in concrete.

When used in freshly mixed concrete, fly ash improves workability and pumpability, reduces the heat of hydration and improves the long-term strength of the concrete. Other benefits include higher impermeability to water, improved sulfate resistance and reduction of alkali-aggregate chemical reactions.

Despite its range of attributes, the fly ash produced from anthracite, bituminous and sub-bituminous coal has a number of potential drawbacks.

Fly-ash concrete (ASTM C618) requires a longer curing time, therefore forms cannot be stripped off as quickly. It also requires much more air-entraining admixture to maintain the proper quantity of air, as much as 300 percent more to preserve the air void system essential to finished concrete. Another negative aspect of fly ash concrete is its reduced resistance to spall.

Blast-furnace slag cement (ASTM C595), produced from steel mill by-products, is a second type of blended cement. The slag content is between 25 percent and 65 percent of the weight of the cement. Slag blends are used where high strengths at early ages are not required, such as in massive footings, dams or piers.

Blast-furnace slag cement has many positive points: it has low heat of hydration, better long-term compressive strength, low permeability and good freeze-thaw performance. However, the mix requires a longer setting time, and overall field experience with slag blends is limited.

A third type of blended cement is manufactured from micro-silica, an industrial by-product derived from ferro-silicon metal production. Micro-silica is 85 to 90 percent silicon dioxide in the form of fine spherical particles. The particles are condensed out of silica fumes given off during metal manufacturing.

The primary use of micro-silica is to produce extremely high-strength concrete. In normal-weight concrete, micro-silica can help the material attain strengths to 20,000 p.s.i., and in a lightweight concrete, up to 11,000 p.s.i.

Micro-silica concrete has low permeability and excellent freeze-thaw resistance, and it develops strength rapidly. However, the mix must contain a high-range water reducer and air-entrainment admixtures in three to four times the amount needed for regular concrete. In application, micro-silica cements are difficult to finish due to their "stickiness"—not a problem for columns, but certainly for slabs.

Admixtures: Just What the Name Implies

Engineers and contractors are concerned with concrete workability, strength, water-tightness and durability. These qualities can be obtained either through selection of suitable mixes (using the proper cement ingredients) or by introducing an admixture during final mixing.

Admixtures can increase the number of air-entrainment bubbles (for resistance to freeze-thaw cycles), reduce water content, retard or accelerate setting, improve workability, reduce permeability or improve the ability of the mix to bond to existing surfaces.

Superplasticizers are a workability agent, used for more than 20 years in Europe but relatively new to the United States. Superplasticizers act as dispersing agents, reducing the amount of mixing water by up to 30 percent (Conventional water reducers lower water requirements by only about 10 percent.)

Workability time for early plasticizers was 30 to 60 minutes depending upon temperature. The newer Superplasticizers have a workability of up to two hours. For example, a higher-quality concrete on a job site may have a one- to two-inch slump; when a superplasticizer is added and the concrete remixed, the slump would go to eight inches without any increase in moisture volume.

Superplasticizers can improve field production by permitting the concrete to "flow" more easily. Water content requirements are reduced, and the end product attains higher strength when the engineer elects to go with this admixture.

Probably the most startling development has been the increase in the upper limits of high-strength concrete.

Non-fluoride, noncorrosive admixtures—or accelerators, as they are commonly known—have been available commercially for about three years.

Calcium nitrate, calcium nitrite and sodium biosynate can be used with other admixtures because they do not have a deleterious effect upon the air void system in concrete.

These accelerators, like the earlier calcium chloride accelerators, are susceptible to shrinkage during the drying phase. The Portland Cement Association cautions all users of accelerators that the product is for developing strength in concrete at an early age and is not an antifreeze agent.

When used in recommended amounts, accelerating admixtures will not reduce the freezing point of concrete by more than three or four degrees.

High-Strength Concrete: The Sky's the Limit?

The upper limits of high-strength concrete continue to be stretched. In the 1950s, 5,000 p.s.i. (pounds per square inch)

concrete was tops; in the 1960s, 7,000 p.s.i. was attained; and by the early 1970s, 10,000 p.s.i. concrete was commercially available.

River Tower in Chicago was built in the 1970s with 11,000 p.s.i. concrete, followed by the Mercantile Exchange Building in the 1980s with 14,000 p.s.i. concrete.

On the horizon are new cement compounds known as macro-defect free (MDF) and new inorganic material systems (NIMS). Examples of these materials produced in the laboratory have tensile strengths in the 15,000 p.s.i. range and compressive strengths up to 35,000 p.s.i.

Molding temperature is 140 F with the cementitious slurry. Because the slurry mixture tends to fill all the internal flaws, NIMS has the tightness and strength of aluminum without its conductivity.

The non-ductile material can be molded, extruded and machined, and if that isn't enough, the material is also highly resistant to freeze-thaw and nearly fireproof.

There are many possible uses for NIMS in the construction industry: curtain wall, partitions, insulation, extruded window and

door frames, structural members, and with additional refinement, engine blocks.

The potential is almost unlimited for new concrete products. Pondering the possibilities, one recalls a famous movie scene from the 1960s where a young business graduate is given some unsolicited advice at a cocktail party: The advisor, a hard-charging businessman, sums up the future in one word—plastics.

Today, the same prophecy could be made for the one substance that architects, engineers and contractors regard as the original "plastic" material—concrete. ■

This article, compiled by Jeffrey L. Beard from an interview with Elwin G. Pell of the Portland Cement Association, is reprinted with permission from the December 1985 issue of Constructor, the official publication of the Associated General Contractors.