Slag Cement in High Performance Concrete

What is High Performance Concrete?

There are several definitions for high performance concrete. Most of these definitions describe concrete with enhanced properties not found in conventional concrete. Some of these properties include higher compressive and flexural strength, lower permeability, lower heat generation, greater resistance to alkali silica reaction and greater resistance to sulfate attack. Slag cement has been used effectively in high performance concrete in North America for over 20 years and is specified by many highway departments in their high performance concrete mixtures.

High performance concrete describes concrete with enhanced properties not found in conventional concrete.

High Compressive Strength

Slag cement increases the strength of conventional concrete and is often a vital component in producing high strength concrete. The higher the percentage of slag cement used (up to 50 percent) in portland cement concrete, the higher the twenty-eight day strengths will be. Many projects have achieved consistent field concrete strengths in excess of 8,000 psi. Additionally, engineers have specified ternary or even quaternary mixtures containing slag cement, portland cement and pozzolans in projects requiring strengths greater than 12,000 psi, such as Reliant Stadium in Houston and Key Tower in Cleveland.

Slag cement has been used effectively in high performance concrete for over twenty years.

The four "super columns" supporting the retractable roof at Houston's Reliant Stadium consistently achieved field strengths of over 15,000 psi, yet maintained a strict temperature differential and peak temperature, using a portland-slag cement-fly ash mixture.

High Flexural Strength

Concrete flexural strengths in excess of 1,000 psi are common with mixes containing slag cement. Flexural concrete strength is increased due to a stronger bond between the cement paste and aggregate particles. This improved bond results from enhanced paste characteristics that also increase compressive strengths. Lambert Field in St. Louis is an example of a project that benefits from the high flexural strengths achievable with slag cement.

The Charenton Canal Bridge, Louisiana's first HPC bridge deck, achieved a chloride permeability of less than 2,000 coulombs, using a 50/50 percent portland-slag cement mixture.

Low Permeability

When slag cement is used as part of the cementitious material in a concrete mixture, it reacts with water and calcium hydroxide ($Ca(OH)_2$) to form additional calcium silicate hydrate (CSH). CSH is the glue that provides strength and holds concrete together. The additional CSH produced modifies the pore structure of the paste resulting in lower permeability. The level of improvement is proportional to the percentage of slag cement in the mixture, normally between 25 and 65 percent. Lower permeability reduces chloride ion ingress and thus reduces the corrosion potential of the structure. Projects such as Wacker Drive in Chicago and Charenton Canal Bridge in Louisiana used slag cement to help reduce chloride ion penetrability to less than 2,000 couloumbs (classified as "low"), by the Rapid Chloride Permeability Test (ASTM C1202).

Slag Cement in High Performance Concrete

Low Heat for Mass Concrete

The I-895 Pocahontas Parkway crossing, with massive footings and columns exceeding 16 ft thick, maintained thermal mass concrete specifications and exceeded 5,000 psi 28-day design strengths using a 75 percent slag cement mixture.

One of the most difficult challenges in designing mass concrete structures is limiting the concrete temperature differential between the center and the surface of the concrete. If this differential becomes too large, thermal cracks can develop in the concrete. Slag cement has been used successfully to substantially reduce the temperature of mass concrete. When used at high replacement rates, slag cement will provide lower heat in mass concrete than concrete produced with low heat cement. Examples include 75 percent slag cement replacement in the I-895 Pocahontas Parkway footings in Richmond, VA and 70 percent slag cement replacement in the Creve Coeur Lake Memorial Bridge in St. Louis.

ASR Mitigation

Alkali silica reaction (ASR) occurs when the alkalis in portland cement react with certain reactive aggregates and water to form an expansive gel that causes concrete to prematurely deteriorate. Slag cement mitigates ASR by combining with the alkalis in portland cement and making them unavailable for the ASR reaction. It also lowers the permeability of the concrete, limiting the amount of water that is available to support the reaction. In some cases, it will lower the total alkali content of the cement paste. Examples of mitigation for reactive aggregates using slag cement include concrete pavements in El Paso, Texas and the Selfridge Air Force Base airfield pavement near Detroit, Michigan.

Mitigation of Sulfate Attack

Sulfate attack occurs in hardened concrete when sulfates, found in seawater, in some soils and in wastewater, react with the tricalcium aluminate (C_3A) in portland cement paste. The reaction causes a material called ettringite to form. Ettringite formation can result in concrete expansion and premature deterioration. The higher the C_3A of the cement, the greater the potential for sulfate attack. Slag cement does not contain C_3A so the higher the percentage of slag cement used, the lower the C_3A of the mixture and the lower the potential for deleterious expansion. Additionally, slag cement reduces the permeability of the concrete and limits the ability of sulfates to penetrate into the concrete. Examples of mitigating sulfate attack with slag cement include William Preston Memorial Bridge in Maryland and the Hap Cremeans water treatment plant in Columbus, Ohio.

Proportioning High Performance Concrete with Slag Cement

Engineers and concrete producers who have successfully incorporated slag cement in their HPC mixtures have used slag cement in ranges from 20 to 80 percent of cementitious material, depending on the application and desired results.

As with all concrete mixtures, trial batches should be performed to verify concrete properties. Results may vary due to a variety of circumstances, including temperature and mixture components, among other things. You should consult your slag cement professional for assistance. Nothing contained herein shall be considered or construed as a warranty or guarantee, either expressed or implied, including any warranty of fitness for a particular purpose.

Many projects have achieved field concrete strengths in excess of 14,000 psi with the use of slag cement.

SCA
SLAG CEMENT ASSOCIATION

Slag Cement Association
6478 Putnam Ford Drive
Suite 219
Woodstock, GA 30189

phone: 678.494.8248
fax: 678.494.8249
e-mail:
info@slagcement.org
web:
www.slagcement.org

About the Slag Cement Association…

The Slag Cement Association is the leading source of knowledge on blast-furnace slag-based cementitious products. We promote the increased use and acceptance of these products by coordinating the resources of member companies. We educate customers, specifiers and other end-users on the varied attributes, benefits and uses of these products.

Printed on recycled paper.