ECOMATERIAL TECHNOLOGIES

TECHNICAL BULLETIN

PozzoSlag®

PozzoSlag is a highly reactive modified pozzolan that meets ASTM C989 performance specifications as a Ground Granulated Blast Furnace Slag (GGBFS) and also meets ASTM C618 performance specifications for Class F fly ash. It is approved by TxDOT and FHWA under a Special Provision as a Modified Class Pozzolan allowing up to 50 percent portland cement replacement.

PozzoSlag has been proven to replace up to 60 percent of portland cement in concrete with excellent results. A mixture containing 60 percent PozzoSlag and 40 percent portland cement will meet ASTM C1157 requirements for performance cement using most portland cements.

PozzoSlag is produced using a unique and innovative process that increases the reactive surface area while optimizing particle size distribution. It is a green cement whose production requires significantly less electricity per ton compared with ordinary portland cement.

PozzoSlag offers a cost-competitive product that:

1. Produces a less porous concrete that has improved durability. Reasons include:
   a. Improved particle size distribution
   b. Improved chemistry of the concrete binder
   c. Reduced alkali-silica reactivity
   d. Improved sulfate resistance
   e. Reduced delayed ettringite formation
   f. Reduced exposure to moisture (less porous)
2. Reduces shrinkage cracks in concrete. Reasons include:
   a. Reduced bleed channels trap water and slow shrinkage (slow curing)
   b. Improved early strength
   c. Reduction in calcium hydroxide
   d. Reduced water demand
3. Improves workability, pumpability, and finishing. Reasons include:
   a. Spherical shape of fly ash
   b. Reduced water demand
4. Reduces set times. Reasons include:
   a. Reduced particle size
   b. Improved contact between reactive materials
   c. Improved rate of cement hydration
5. Reduces surface problems in concrete such as dusting and delaminating. Reasons include:
   a. Reduced bleed water
6. Improves set times: Offers the customer a consistent quality product, removing the performance variations often experienced when the coarseness of the fly ash varies from shipment to shipment.
7. Converts cement and concrete into environmentally friendly products by: (a) reducing CO2 emissions and energy requirements associated with portland cement production, and (b) offering an environmentally friendly way to dispose of fly ash waste products from coal-fueled electric power plants.

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Explanation for PozzoSlag Mechanism of Action

1. The fine material components in PozzoSlag reduce porosity and increase strength. The reduced paste porosity during curing reduces bleed water and slows shrinkage rates, resulting in improved curing conditions and reduced shrinkage cracks.
2. The higher rate of cement hydration for the processed fraction of portland cement creates higher early strength, reduced setting time, and accelerated formation of calcium hydroxide available for pozzolanic reactions.
3. The increased contact area between cement and fly ash, and increased chemical reactivity of the blend during the production process, create improved points of contact between the materials and their intermediate products, which result in improved efficiencies of the desired chemical reactions.
4. As percentages of PozzoSlag are increased to optimum levels, the pozzolanic reaction causes the densification of concrete microstructure.

The first Eco Material plant for the production of PozzoSlag:

1. Is located adjacent to the Limestone Power Plant near Jewett, Texas. Fly ash is conveyed directly from the power plant to Eco Material's production facility.
2. Had an initial production capacity of about 150,000 tons per year.
3. Is owned and operated by Eco Material Technologies.
4. Is located within economical trucking distance to the Houston, Dallas-Fort Worth, and Austin markets.

Plant Expansion

1. The capacity of the plant was increased to 300,000 tons per year in early 2006.
2. Process changes were made to improve the early strength and set times of PozzoSlag.

Eco Material plans to establish other plants and products in the Texas market according to market demand.

Durability

PozzoSlag concrete is stronger and more durable because it is less permeable. It has a reduced tendency for shrinkage cracks, dusting, and delaminating. It reduces alkali-silica reactivity problems in concrete and increases sulfate resistance. PozzoSlag also reduces the potential of delayed ettringite formation. Tests at Penn DOT have shown improved durability through freeze-thaw cycles.

Economic Incentives

1. PozzoSlag concrete will typically cost less to produce compared to a typical blended cement concrete because of the higher replacement factor versus Class C or F fly ash. Also, compared to slag and lower chemical admixtures, it is readily available.
2. PozzoSlag concrete will typically save on contractor labor costs because the concrete will be easier to work at lower slumps and set faster, allowing reduced hours for finishing.

Reduced Tendencies to Crack—"Autogenus Healing"

PozzoSlag concrete has reduced tendencies to crack because PozzoSlag decreases the water demand required for workability, increases the early tensile strength, and restricts the pore structure of concrete. It has autogenus healing due to the high pozzolan content in the concrete. For example, if you break a C109 test cube made with PozzoSlag on 7 days (not to total failure, merely decompression loss) and put it back in the water bath, it will "heal over" and regain strength versus cubes still left

in curing and break as strong or stronger as cubes not yet compressed in 28 days. The same holds for stress and micro cracks in concrete. With PozzoSlag, they often heal so quickly that the original crack is never noticed.

1. Plastic shrinkage cracks are reduced because of the entrapment of water within the pore structure of the concrete and the reduced time period between placing and initial set.
2. Drying shrinkage cracks are reduced because tensile strengths develop faster than shrinkage normally occurs.
3. Thermo-cracking is significantly reduced due to the reduced content of portland clinker minerals in the concrete and much lower heat of hydration.

Reduced Set Times

PozzoSlag concrete has initial and final set times that compare closely with concrete produced with much lower percentages of Class C fly ash. Set times will be greatly improved for concrete produced using Class F fly ash or higher percentages of Class C fly ash. Varying particle size distribution and/or the percentage of portland cement can control set time characteristics of PozzoSlag. Varying these control variables will help PozzoSlag concrete set satisfactorily in different weather conditions.

Strength Development

PozzoSlag can be used at 60 percent portland cement replacement to produce concrete with 3800 psi compressive strength in 28 days using 420 lbs. of total cementitious material. Strength development is a function of water-to-cementitious ratios and not the percentage replacement.

Workability

It is well known that the spherical shape of fly ash particles improves the workability of concrete. The Eco Material technology closely controls the grinding of fly ash so as not to destroy the spherical shape. The increased ratio of solids volume to water volume produces a paste with improved plasticity, more cohesiveness, and fewer tendencies to segregate.

Pumpability

PozzoSlag improves pumpability for the same reasons it improves workability. The lubricating effect of the spherical fly ash particles, and the increased ratio of solids to liquid, make concrete less prone to segregation.

Bleeding and Permeability

PozzoSlag is finer than most cementitious materials. The increased fines help block possible bleed channels. PozzoSlag reacts with available calcium hydroxide to generate additional cementitious compounds that act to block bleed channels, filling pore space and reducing the permeability of hardened concrete. The reduction in bleed water helps reduce problems such as dusting, delaminating, and shrinkage cracks.

Alkali-Silica Reactivity

PozzoSlag is composed primarily of Class F fly ash. Class F fly ash is effective in inhibiting or reducing expansive reactions resulting from the alkali-silica reaction. In theory, the reaction between the very small particles of amorphous silica glass in fly ash and the alkalis in the portland cement ties up the alkalis in a non-expansive calcium-silica gel, preventing them from reacting with silica in aggregates, which can result in expansive reactions. ASR testing per ASTM C441 shows that mortar

bars made from Eco Material cement have a considerably better resistance (92 percent improvement) in respect to alkali-silica reactivity than mortar bars made with portland cement.

TxDOT testing for ASR reactivity using ASTM C1260 reflected dramatic reductions in ASR reactivity as percentages of PozzoSlag were increased.

Sulfate Resistance

Sulfate resistance testing per ASTM C1012 show that mortar bars made with PozzoSlag and cement have improved sulfate resistance over reference mortar bars made with portland cement and Class F fly ash.

Delayed Ettringite Formation (DEF)

The main reasons for the reduced primary and, especially, delayed ettringite formation (DEF) with the use of PozzoSlag are as follows:

a. By replacing portland cement with PozzoSlag, the total amount of C3A for ettringite formation (see below reaction) is reduced.

   i. $C_3A + 3\ CaSO_4 + 26\ H_2O = 3\ CaO*Al_2O_3*3\ CaSO_4*32\ H_2O$ – ettringite

b. Due to the pozzolanic reaction of PozzoSlag with Ca(OH)2, the concrete porosity becomes much finer, which prevents the ingress of water (H2O) required for ettringite formation and significantly reduces the amount of micro defects required for re-crystallization of ettringite (DEF).

c. Reduced cracking caused by drying shrinkage of the concrete containing high volumes of PozzoSlag (HVCP concrete) also restricts the damage-promoting transport of moisture and other agents required for DEF.

Quality Control

Although PozzoSlag will meet the specifications for Class F fly ash and Grade 100 slag from a performance aspect, it is actually a very different product. PozzoSlag is specially engineered with added cementitious materials, added surface activation, and specific controls for particle size distribution. PozzoSlag initially will be produced using fly ash from only one power plant. Varying coal sources and environmental specifications currently influences the quality of unprocessed fly ash. The PozzoSlag production process addresses these problems and delivers a consistent product.

State and Federal Approval for Highway Construction

The Texas Department of Transportation Special Provisions currently allow a maximum of 50 percent replacement using PozzoSlag. The FHWA has also approved usage up to 50 percent.

Energy Reductions

Portland cement production requires 3.5 million BTUs of fuel per ton and 100 kWh of electricity per ton. PozzoSlag production requires only 25 kWh of electricity per ton.

Slag Competition

PozzoSlag performs equally to ground granulated blast furnace slag without the 40-50 percent of calcium oxide generally found in GGBFS. PozzoSlag accomplishes the same reactivity with less than 20 percent calcium oxide or strength activity indexes equal to 100 percent portland. It supplies the right ingredients to prevent ASR and resist sulphate attack, while providing early strength at 50 percent replacement levels of ordinary portland cement or higher.