ECOMATERIAL TECHNOLOGIES
A CRH COMPANY

TECHNICAL BULLETIN

Ternary Concrete Mixes

with Cement, Slag, and Fly Ash

For many concrete producers, meeting the engineers' concrete performance standards, the contractors' and finishers' field performance needs and the owner's budgetary limitations generates the need to utilize supplementary cementing materials in addition to portland cement. Historically, the two materials typically considered have been either ground granulated blast furnace slag (GGBFS) from iron ore blast furnaces or fly ash from coal combustion power plants.

A new trend in the market is the combination of both slag and fly ash with portland cement to create economically attractive performance concrete mixes for everyday concrete. Three-way mixes have been utilized in the past, but typically for specialty high strength concrete where higher reactivity silica fume or metakaolin have been combined with either fly ash or slag to generate very high early strengths.

Both fly ash and slag rely on the excess lime/calcium hydroxide from portland cement that is found in hardened concrete. This non-durable, water-soluble material called efflorescence is visible as a white chalky deposit on the surface of concrete. Fly ash and slag combine with the

calcium hydroxide to create the same durable calcium-silica-hydrate (CSH) "glue" as portland cement. This reaction is a slower, long-term reaction that will increase long-term concrete strength and reduce concrete permeability, thereby increasing the durability of concrete.

Concrete produced with a combination of fly ash, slag, and portland cement has been proven to enhance concrete performance by producing higher long-term strengths, improving workability while requiring less water, and reducing efflorescence and permeability.

Fly ash is a reactive spherical particle, typically finer than cement, that provides workability to concrete because of its shape, and typically allows for strength and durability enhancing lower water contents. Strength and durability results may vary based on the fly ash chemistry. Low oxide/high calcium Class C fly ash may provide higher early concrete strengths than a high oxide/low calcium Class F fly ash. Class F fly ash is typically superior to a Class C fly ash in mitigating damage from both sulfate and alkali–silica damage to concrete.

Slag requires grinding to develop the fineness and reactivity to meet the market demand. Slag can typically replace more cement than fly ash for the same strength levels, depending on the fineness of the grind, but because of its angular shape, may not provide any improvements in workability and water reduction.

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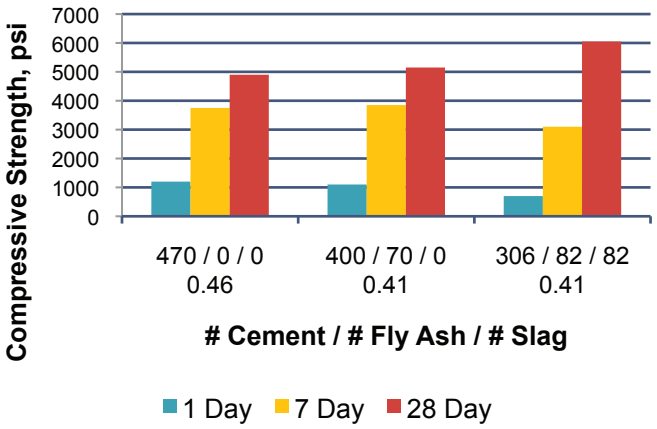
TERNARY CONCRETE MIXES WITH CEMENT, SLAG, AND FLY ASH

Fly ash has been used to replace in excess of 35% of the cement in concrete, and slag has been used to replace in excess of 50% of the cement in similar applications. In reality, cement is typically replaced by fly ash at 15% to 25%, and by slag at 40%.[1] Coincidentally, in many markets, the combined cost for cement and 20% fly ash is equivalent to a mix with cement and 40% slag. At greater rates of cement replacement for either material, the early strength and setting for flat work can be delayed, and in some cases, the 28 day design strength may have to be extended to 56 days or more. In either case, construction needs and schedules will impact the cement replacement percentage.

By combining the reactivity, workability and water reduction of the lower priced fly ash with the reactivity of slag that allows for greater portland cement replacement, more economical, high quality concrete can be produced. The typical percentages for both fly ash and slag are around 15% to 17%, for a combined replacement of cement of 30% to 35%.

The strength graph depicts the strength and water reduction of a Class C fly ash compared to a portland cement control mix and in combination with slag, with the cost of cementitious materials decreasing while 28 day strengths increase.



When silo space allows, blends of cement, fly ash and slag can be the most economical choice for the ready mix producer to meet the engineers', contractors', and finishers' needs in the field.

For more information or answers to questions about the use of fly ash in specific applications, contact your nearest Eco Material Technologies Technical Sales Representative or call 1-770-684-0102.

1 "Fly Ash, Slag, Silica Fume and Natural Pozzolans", Portland Cement Association, 2002.

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