



# information

ENVIRONMENTAL  
COUNCIL of CONCRETE  
ORGANIZATIONS

5420 Old Orchard Road  
Skokie, Illinois  
60077-1083  
800 994-ECCO (3226)  
FAX (847) 966-8389

## Reclaimed Industrial Byproducts Key to Concrete of the Future

Reclaimed, recyclable industrial byproducts — which in past years would have been dumped in landfills — now are key components to the high-performance concretes (HPCs) of the future. An immediate environmental benefit of the use of reclaimed industrial byproducts in concrete is lessened pressure on landfills.

Another is that with their use, less cement is needed for a given application, so use of these cementitious byproducts in concrete means a reduction in the amount of energy consumed by the cement manufacturing industry, and parallel reductions in carbon dioxide and water vapor emissions.

### Adding value

And use of these reclaimed materials in high-performance concrete provides added value for the owner of a concrete structure or pavement.

Surprisingly, this added value can come without significant upfront added costs. High-performance concretes made with reclaimed,

recyclable industrial byproducts — such as coal fly ash, silica fume and ground granulated blast furnace slag (GGBF) — result in stronger, more durable structural elements, allowing designers to specify fewer elements, all things being equal, with equivalent first-cost savings.

HPC using reclaimed industrial byproducts has been used in structural applications in private sector-owned high-rise buildings for years, but DOTs and public sector owners have been hesitant to specify it due to a lack of experience in bridge or pavement applications. This lack of experience is being rectified through an active research program sponsored by the Federal Highway Administration (FHWA) and interested state DOTs.

Ongoing tests by FHWA and state DOTs utilizing prestressed, precast HPC structural elements are proving its value-added benefits in the field. Reduced manufacturing, delivery and construction costs are among the reasons for the savings.

### “Waste” materials and HPC

High-performance concrete, also referred to in the literature as “durable concrete,” is an engineered concrete made up of the classic components of water, portland cement and fine and coarse aggregates, but with a twist. With HPC, materials and admixtures are carefully selected and proportioned to realize high early strengths, high ultimate strengths and high durability beyond conventional concrete.



Coal-fired power plant with electrostatic precipitators visible. Photo courtesy of American Electric Power.





And the startling fact is that some industrial “waste” materials of a few decades ago now are integral elements of this new engineered concrete. These admixtures — principally fly ash, silica fume and GGBF — add both strength and durability to the concrete.

HPC can provide enhanced mechanical properties in precast concrete structural elements, including higher tensile and compressive strengths, and heightened modulus of elasticity (stiffness).

In frost-prone regions the benefits of HPC are great. In the case of parking garages and decks, or transportation structures like bridges and overpasses, the enhanced durability of HPC means it strongly resists penetration of chloride-laden snow and ice melt water. This results in longer life for the reinforcing steel within, and a reduction in spalling, cracking and associated repairs.

But HPC is for use in mild climates as well. Oceanside apartments or condominiums, or marine piers and breakwaters, will benefit from use of durable HPC as it protects reinforcing steel from salt water splash and spray.

HPC and conventional concrete differ primarily in the proportions in which its fundamental elements are mixed, and with the admixtures that are used. A low water/cement ratio, perhaps as low as 0.35, is required, achieved by use of a high-range water-reducing admixture.

### Fly ash boosts performance

Fly ash, termed a CCB (coal combustion byproduct), is the residue of the burning of

pulverized coal in thermal power plants. The ash particles are collected mechanically or by electrostatic precipitators.

Generally, 15 to 20 percent of burned coal takes the form of ash. In 1995 the annual production of CCBs in the U.S. was estimated at nearly 82 million metric tonnes (90 million short tons), with over 550 million metric tonnes worldwide (1994).

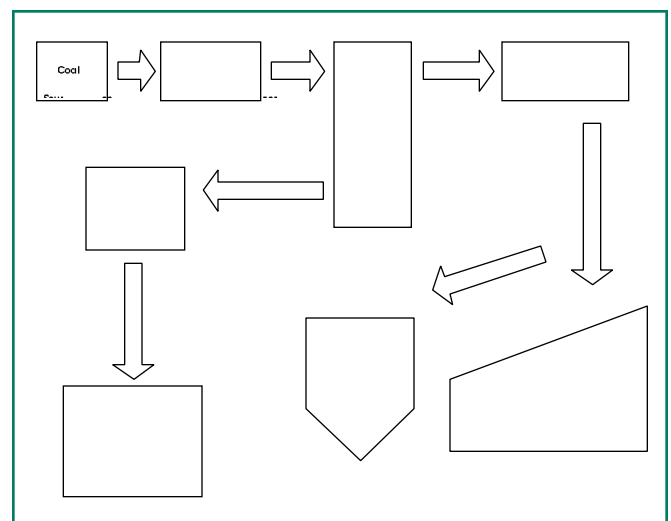
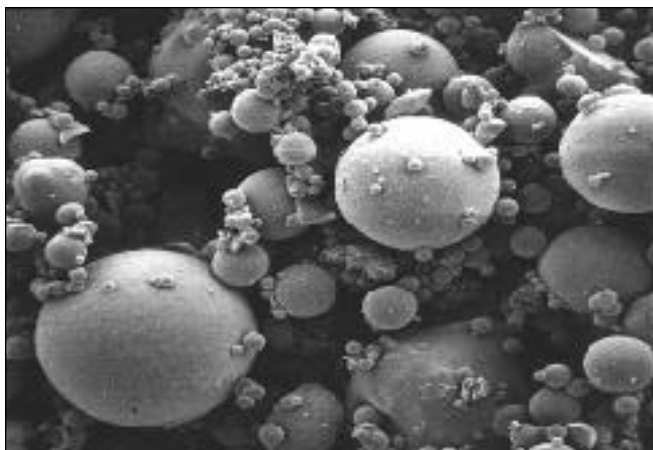
Fly ash is a pozzolan, meaning it is a siliceous and aluminous material that, in the presence of water, will combine with an activator (lime, portland cement or kiln dust) to produce a cementitious material, according to *Fly Ash Facts for Highway Engineers*, a publication of the FHWA, and authored by the American Coal Ash Association (ACAA).

Initially, this ash went right up the stack, but as awareness of the problems with air pollution increased, technologies were developed to make it easier to remove the ash from the stack stream. This material mostly was land-filled, but high landfill costs — along with the need to develop profit centers — spurred electric utilities to find markets for the pozzolanic material.

Fly ash use on federal-aid highway projects was encouraged by its classification as a “recovered” product under the federal Resource Conservation and Recovery Act (RCRA), which generally mandates use of fly ash in cement or concrete in construction projects using \$10,000 or more of federal funds.

The American Society for Testing and Materials (ASTM) classifies fly ash into Class C and Class F categories. Class C, with a higher calcium oxide content (CaO, or “lime”), comes from the burning of western sub-bitu-

Class F fly ash magnified 600X.



minous or lignite coals, and Class F is derived from bituminous eastern coals. While both types perform well, recent research indicates that Class F fly ash is better suited for fighting a common malady of concrete, alkali-silica reactivity (ASR).

### Silica fume rebounds

Another industrial “waste” byproduct which would otherwise be landfilled, silica fume has a most useful role as an admixture in promoting durable concrete.

Silica fume is a byproduct of the reduction of high-quality quartz with coal or coke and wood chips in an electric arc furnace, during the production of silicon metal or ferrosilicon alloys. The fume is condensed from gases escaping from the furnace and mostly consists of superfine, spherical silicon dioxide particles.

From 1977 on, silica fume began to find its way into U.S. high-rise construction as an additive to concrete, to which it imparts durability and strength. In the 1980s it was used extensively in high-profile high-rise projects, in some cases producing concrete which exceeded 14,000-psi compressive strengths.

But when the market for speculative high-rises collapsed in the early 1990s, sales of silica fume took a hit. However, most silica fume can be used in parking garages and bridge decks, where it helps block migration of chloride ions to reinforcing steel.

Use of silica fume has stabilized as the fraction of the product placed in commercial high-rises moves into bridge decks and bridge substructures. Silica fume use is growing as commercial projects move off the drawing boards. Its use in transportation

structures currently is being validated by the ongoing FHWA/state DOT research into HPC.

### Adding value with GGBF slag

Like fly ash, use of blast-furnace slag in concrete has been practiced in Western Europe and Japan since the early 1940s. Blast furnace slag is the byproduct of the manufacture of molten iron, resulting from the fusion of limestone and other fluxes with the ash from coke and silica and alumina from iron ore.

While air-cooled slag has been used for decades for noncritical applications such as railroad track ballast, or landfilled or left in heaps at steel mills, in a processed state as ground granulated blast-furnace slag (GGBF) it takes on much higher value as an admixture to concrete.

According to ASTM, GGBF slag is a cementitious, glassy, granular material formed when molten blast-furnace slag is rapidly chilled by immersion in water. This chilling creates a granular product which is then ground to spec and used as an admixture in concrete where it provides improved performance over conventional concrete.

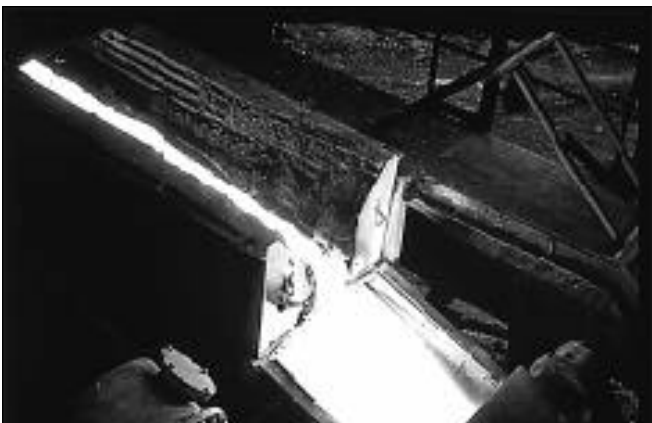
Demand for GGBF slag manufactured to spec is such that it rarely is seen outside the “Rust Belt” in which the iron and steel industry is situated. Its marketability was further enhanced in 1996 when the Environmental Protection Agency ruled that it was a “recovered” product under the RCRA, the same status as fly ash as described above.

Now GGBF slag may be substituted for fly ash in concrete mixes in federal projects, within limitations.

### Not just for HPC

Other recyclable industrial wastes are useful in concrete applications not related to HPC, adding value and enhancing projects.

For example, Syndcrete is a lightweight, precast architectural concrete composite using recyclable industrial byproducts. It’s used in custom-made kitchen and



---

Jet process granulator produces slag in a glassy, amorphous state that suits portland cement concrete.

Photo courtesy of Holnam Inc.

---





bath applications for style-conscious customers. The cement-based product uses fly ash as a substitute for 20 percent of cement, and also incorporates waste polypropylene fibers from carpet manufacture. Other recycled materials such as metal shavings and glass chips can be incorporated for aesthetic appeal, reported the Environmental Building News.

New research (ACI Materials Journal of the American Concrete Institute, Jan.-Feb. 1996) indicates that foundry sand — 90 percent of which is now landfilled — may serve as partial replacement for fine aggregate in making masonry blocks. The research indicated that masonry blocks containing 35 percent used foundry sand passed ASTM requirements for compressive strength, absorption and bulk density.

Even reclaimed industrial wood fibers are finding a way into masonry blocks. A European technology — Faswall blocks — which incorporates cement and recycled wood fiber from processing plants into masonry blocks, was imported to the U.S. in the early 1990s.

The lightweight blocks are strong and durable, can be used above- and below-grade, and can be worked with conventional saws and routers.

The simplest use for these blocks is as permanent forms for concrete walls. The interlocking blocks are stacked dry,

fitted with rebar, and voids filled with conventional concrete, reported the Environmental Building News.

### **Not a dream, but real**

Structural and pavement portland cement concrete utilizing reclaimed industrial byproducts — with immediate and long-term benefits to the environment — is not just a dream of the future.

It is here and now, and here to stay, prescribed by economic forces as well as government regulations. And applications are growing as research continues.

The ease of use and functionality of reclaimed industrial byproducts in concrete is just one more reason to think of concrete as the environmentally friendly building medium.



---

Texas DOT U-beam, prestressed girders of high-performance concrete utilize industrial byproducts to attain their high-strength and durability.

Photo courtesy of Texas Department of Transportation.

---

© 1998 by  
the Environmental Council of Concrete Organizations

The Environmental Council of Concrete Organizations  
is a coalition dedicated to promoting  
the environmental benefits of concrete and its role  
in safe and sustainable construction.

ECCO members are companies, organizations,  
and individuals affiliated with the concrete industry.  
Together, they are committed to developing and disseminating information on the  
environmental benefits of concrete and concrete products.

---