

Utilization of slag cement in concrete lessens the burden on landfills, reduces emissions and conserves energy.

One of the great benefits of slag cement is that portland cement can be replaced in relatively large percentages using mainstream technology.

RECOVERING A VALUABLE PRODUCT

Blast-furnace slag is produced in a blast furnace during the reduction of iron ore to iron. It consists of non-metallic minerals, which are tapped off from the blast furnace while molten. By processing blast furnace slag into slag cement or slag aggregate, the material is diverted from landfills. Utilization of slag cement in concrete not only lessens the burden on landfills, it also conserves a virgin manufactured product (portland cement), reduces air emissions at the blast furnace and through the avoided manufacture of portland cement, and decreases the embodied energy required to produce the cementitious materials in concrete.



Figure 1: Slag cement not only reduces energy, emissions and virgin material requirements in concrete, it also lightens the concrete, so exposed concrete surfaces reflect more light and help reduce the urban heat island effect.

HOW DOES SLAG CEMENT MAKE CONCRETE GREENER?

Concrete is an inherently green material that is highly durable. It can be used to construct energy-efficient building systems, and reduces the "heat island" effect because of its lighter color. Slag cement can make concrete an even greener material. One of the great benefits of slag cement, from an environmental perspective, is that the replacement of large proportions of portland cement with slag cement in concrete is a commonly used mainstream technology. Typical mixture designs for structural or paving concrete normally use substitution rates between 25 and 50 percent; high-performance and mass concrete applications can use substitution rates up to 80 percent. These high proportions for slag cement dramatically reduce the embodied material, energy and emissions in a cubic yard of concrete.

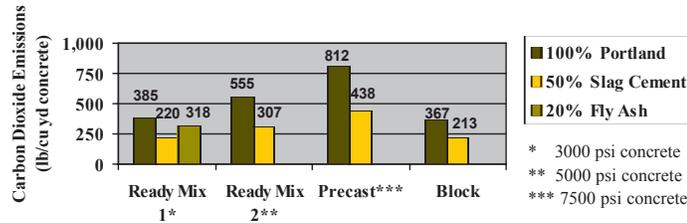
WHAT IS A LIFE CYCLE INVENTORY?

A life cycle inventory (LCI) documents the material inputs, energy inputs and emission outputs associated with manufacturing a product. An LCI has been performed on concrete made with portland cement concrete mixtures for ready mixed concrete, precast concrete and block applications¹. Another LCI study has documented the same mixtures for concrete substituting slag cement for a portion of the portland cement². Also, a limited analysis of a typical mixture incorporating fly ash was performed¹. The results of these studies clearly show the environmental advantage of incorporating slag cement into a concrete mixture.

A life cycle inventory of concrete made with slag cement shows that for each cubic yard of concrete, greenhouse gas emissions can be reduced by almost one-half, energy reduced by up to one-half, and material extraction reduced by up to one-seventh.

CARBON DIOXIDE REDUCTION

Figure 2: Effect of Slag Cement on Embodied Greenhouse Gas Reduction in Concrete



CO₂ emissions significantly since the early 1980's and continues to develop methods that minimize the release of greenhouse gasses. One approach is by offering alternative cementitious materials, like slag cement, to partially replace portland cement in concrete mixtures. Figure 2 illustrates the benefits of substituting 50 percent slag cement in various concrete mixtures. Between 165 and 374 pounds of CO₂ are saved per cubic yard of concrete by using a 50 percent slag cement substitution, a 42 to 46 percent reduction in greenhouse gas emissions.

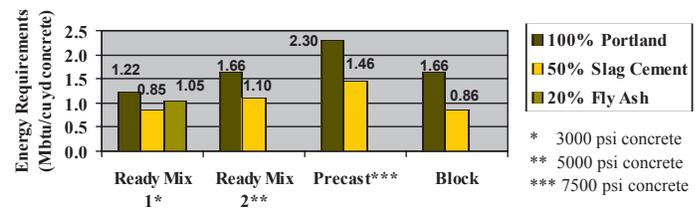
Carbon dioxide (CO₂) is classified as a greenhouse gas. In portland cement manufacturing, almost one ton of CO₂ is released for every ton of portland cement produced. The cement industry has reduced



ENERGY SAVINGS

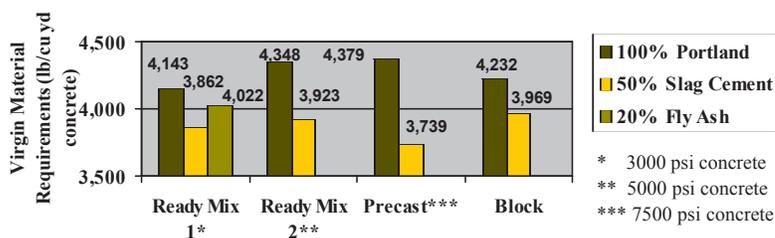
Slag cement requires nearly 90 percent less energy to produce than an equivalent amount of portland cement. Reducing the use of portland cement in concrete by substituting a portion of it with slag cement significantly reduces the embodied energy in a cubic yard of concrete, since portland cement constitutes 70 percent or more of this energy in concrete. Figure 3 shows that embodied energy can be reduced by 370,000 to 840,000 btus with 50 percent slag cement substitution. This is a 30 to 48 percent reduction in embodied energy per cubic yard of concrete.

Figure 3: Effect of Slag Cement on Embodied Energy Reduction in Concrete



REDUCED MATERIAL EXTRACTION

Figure 4: Effect of Slag Cement on Embodied Virgin Material Extraction in Concrete



Raw materials for portland cement are gathered through mining operations. A ton of portland cement actually requires about 1.6 tons of raw material, because of mass lost due to emissions and other factors. Substituting 50 percent slag cement can save between 281 and 640 pounds of virgin material per cubic yard of concrete, a reduction of between 6 and 15 percent (Figure 4).

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SLAG CEMENT AND THE ENVIRONMENT

COMPARISON WITH FLY ASH CONCRETE

Substituting fly ash for portland cement is another way to make concrete greener. Fly ash is a pozzolan and a by-product of coal combustion for electric power facilities. However, fly ash is normally used in quantities between 15 and 25 percent, as compared with substantially higher substitution levels for slag cement (which is a hydraulic cement). One life cycle inventory study investigated fly ash substitution of 20 percent for a 3,000 psi ready mixed concrete mixture. Table 1 shows the percent savings comparing 35 and 50 percent slag cement with 20 percent fly ash substitutions (typical values for each material). In this example, slag cement provided one and a half to more than twice the savings in emissions, energy and extracted material when compared with fly ash.

Table 1: Environmental Benefits Comparison of Slag Cement and Fly Ash in 3,000 psi Concrete

Environmental Benefit (Substitution Rate for Portland Cement)	Slag Cement (35%)	Slag Cement (50%)	Fly Ash (20%)
Carbon Dioxide Emissions Savings*	30%	43%	17%
Energy Savings*	21%	30%	14%
Reduction in Extracted Material*	5%	7%	3%

*Percentages listed for savings in carbon dioxide, energy and material are based on 100 percent portland cement systems compared with systems containing slag cement or fly ash substitution.

LIGHTER COLOR ENHANCES THE ENVIRONMENT

Slag cement is whiter in color than portland cement or other cementitious materials, such as fly ash or silica fume (Figure 5). This results in lighter-colored concrete products with higher reflectivity. Lighter-colored concrete has multiple environmental benefits:

- Lighter colored pavements, like parking areas and streets, produce brighter environments with higher visibility and improved safety.
- The lighter color of slag cement concrete also helps reduce the heat island effect in large metropolitan areas. Since urban areas have a higher concentration of structures and surfaces that absorb heat, they tend to experience higher temperatures than their rural neighbors do. Buildings and pavements that are lighter in color reflect more light (high albedo surfaces). This helps minimize the heat island effect, which reduces the energy needed for cooling, and lowers ozone levels.



Figure 5: Comparison of various finely divided cementitious materials (Clockwise, from top: slag cement, silica fume, fly ash and portland cement).

Figure 6 : Effect of Slag Cement on Concrete Reflectance

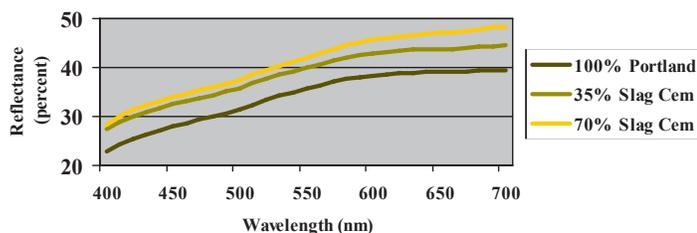


Figure 6 shows how slag cement reflectivity is improved at various levels of the visible spectrum. Figure 1 shows the light color of concrete elements produced from slag cement concrete.

Slag cement results in lighter colored pavements and exposed concrete; this improves visibility and safety, and also helps reduce the urban heat island effect.



SLAG CEMENT AND THE ENVIRONMENT

LEED CREDITS

Leadership in Energy and Environmental Design (LEED) is a system developed by the United States Green Building Council to rate a building's environmental performance³. This system has become the principal method by which buildings can achieve green building certification. The system is based on credits earned in five major categories. Slag cement can positively impact several credit categories including:

- Site credit for reduction of heat islands: Use of high-albedo materials like concrete produced with slag cement.
- Materials credit for building reuse: Slag cement makes concrete structures more durable.
- Materials credit for recycled content: Slag cement is a recycled material used in concrete.
- Materials credit for use of local/regional materials: Slag cement can be considered a local material in many areas.

For more information on the LEED system, visit www.usgbc.org or contact a LEED-accredited professional.

FEDERALLY-AIDED PROJECTS

In 1996 the Environmental Protection Agency recognized slag cement as a "recovered" product under the Federal Resource Conservation Recovery Act. This classification requires that slag cement be specified in concrete on Federally funded projects. For more information on the EPA's Comprehensive Procurement Guidelines—a key component of the federal government's "Buy Recycled" program—visit the website www.epa.gov/epaoswer/non-hw/procure/index.htm.

References

1. Nisbet, Marceau and VanGeem, Environmental Life Cycle Inventory of Portland Cement Concrete (SR 2137a), Portland Cement Association, Skokie, Illinois, 2002.
2. Marceau, M. and VanGeem, M., Life Cycle Inventory of Slag Cement Concrete, letter report from Construction Technology Laboratories to the Slag Cement Association, Sugar Land, Texas, 2003.
3. ECCO EV 27, LEED Green Building Rating System and Concrete, Environmental Council of Concrete Organizations, Skokie, Illinois, 2002.

The EPA's Comprehensive Procurement Guidelines require that slag cement be specified for any concrete used on Federally-funded projects.



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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.



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