Slag[1]

What is it?

Blast-furnace slag is the by-product of molten iron production in a blast-furnace. The process of rapid cold-water quenching and grinding the slag to the fineness of Portland cement (PC) produces what is then termed ground granulated blast-furnace slag (GGBS), a material with latent hydraulic cementitious properties. A latent hydraulic material is one that forms cementitious hydrates in reaction with water but only in the presence of other materials such as lime and calcium sulfate, or PC.

Please visit http://www.slagcement.org/ for answers to many more questions regarding slag cement.

What is so sustainable about it?

The primary environmental advantage of using GGBS is the reduction in CO2 associated with cement production through utilization of industrial waste. Use of slag in concrete is considered using recycled material by LEED, and contributes to the Materials Resources Credit 4 (Recycled Content). *See LEED section for sample calculation*. Additionally, GGBS can have many benefits over PC concrete including heat reduction, sulfate resistance, mitigation of alkali-silica reaction, and enhanced resistance to chloride ingress. Levels of up to 80% of total cementious content have been used, and tests have shown these most effective in sulfate resistance.

Furthermore, GGBS gives concrete a lighter visual appearance, increasing the surface solar reflectivity index (SRI). Higher SRI can help mitigate the heat island effect in our urban areas, where dark surfaces absorb and retain solar radiation, increasing urban air temperatures above ambient temperatures in outlying areas. The SRI is the measure by which LEED assesses the albedo ("coolness") of roofing and hardscape material in Sustainable Sites Credit 7.1 (Heat Island Effect – Nonroof) and 7.2 (Heat Island Effect – Roof).

Thus, as well as reducing PC, using GGBS in concretes can give it many desirable properties aside from environmental benefits.

What should I watch out for?

Like fly ash, the rate of strength development in high volume GGBS concrete may be significantly lower than that of the equivalent PC concrete, particularly in cold weather. This may result in increased formwork striking times. To improve the early rate of strength gain, GGBS may be very finely ground, but then this may adversely affect its heat reduction properties.

[1] Thanks to contributions from Bryan Marsh and Sarah Kaethner, Arup

Low cement replacements (less than 30%) will likely not affect the rate of early strength gain. However, technical benefits such as resisting chlorides and aggressive ground conditions may not be realized until higher replacement levels (35-50%).

The reaction of GGBS in concrete is accelerated by heat to a greater extent than PC. Its effectiveness in reducing heat in very large sections may be less effective than in smaller ones.

If using GGBS as cement replacement for sustainability reasons, be careful that GGBS has not been merely added to the mix on top of the conventional proportion of cement. To truly contribute to the environmental savings, the cement content should not be greater than an equivalent PC concrete mix. For example, if your traditional mix has 6 sacks of cement, than a "50% replacement mix" of 3 sacks of cement and 3 sacks of slag has more environmental benefit than a "50% replacement mix" of 3.5 sacks of cement and 3.5 sacks of slag.

Where is it available?

The manufacture and distribution of GGBS is well organized on a commercial scale in many countries and GGBS concrete may be as readily available from concrete suppliers as PC concrete. Production of GGBS is, however, localized to iron-making areas and may thus have been transported significant distances for use in concrete. A map of slag production sites in the US is available at
http://www.slagcement.org/shared/custompage/custompage.jsp?_event=view&_id=445505_U128801__147915

Concrete contractors in the California area are typically very familiar with using GGBS in mixes for structural concrete. Nonetheless, it is always good practice to check with local contractors if planning to spec cement replacement with GGBS. They will often provide several sample mixes from similar past projects. This will allow better understanding of any limitations to the maximum specifiable. Early engagement of the contractor also provides information on trends in availability and potential impacts to cost and schedule.

What are the standards for it?

The composition of GGBS from a single source is generally very consistent as the chemistry of the slag is controlled by the iron production process. However, the composition may vary considerably between sources. Standards for GGBS and its use in concrete are primarily covered by ASTM C989 and ACI 233.

How do I specify it?

See Specs section below

How do I calculate it for LEED?

The calculation below is extracted from *LEED-NC™Guide:Using Slag Cement in Sustainable Construction* found at

http://www.slagcement.org/download/123321_U128801__193293/LEED_Guide06_final%20%2811-13-06%29.pdf

TABLE 3 –EXAMPLE OF CONCRETE RECYCLED CONTENT WITH SLAG CEMENT (LEED 2.1)

Concrete Component	Weight (lb/cubic yard)	Recycled Content	Percent by Weight
Slag Cement	284	100%	7.1%
Portland Cement	284	0%	7.1%
Aggregate	3200	0%	79.9%
Water	237	0%	5.9%
Total	4005		100%

Value of concrete recycled content is then calculated as follows:

Recycled Content Unit Value ($) – (% Post-Consumer and 1/2 % Post-Industrial Recycled Content) x (Material Cost) – (1/2 x 7.1 % Slag Cement) x ($100/cy Concrete) – $3.55/cy

Contribution toward recycled value – (Material Quantity) x (Recycled Content Value) – (5,000 cy Concrete) x $3.55/cy – $17,750

How do I incorporate this into my specifications?

Although a sample spec is shown below, it is always good practice to have a discussion with local contractors if planning to spec cement replacement with either fly ash or GGBS. Concrete contractors in the SEAONC area are typically very familiar with using fly ash and GGBS in mixes for structural concrete and may have recommended language for specific project conditions.

Under 03300

CONCRETE MATERIALS

Portland Cement

It is the owner's intent to utilize materials that will lessen the impact on our environment and maximize the use of recycled or “green” building materials such as high volume fly ash and/or slag products.

A. Fly Ash –
    1. Conforming to ASTM C 311 and ASTM C 618, Class C or F, with the maximum Loss on Ignition (LOI) shall be less than 3%.

2. Substitution of fly ash at the minimum rate of 20% (change per project conditions) by weight of cement. [The maximum rate of substitution shall be 50% (change per project conditions) by weight of cement (optional).] Use of fly ash substitution shall not increase overall of cementitious content required to meet strength and performance requirements.

B. Ground Granulated Blast Furnace Slag Cement(GGBFS)

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1. Slag Cement shall conform to ASTM C989 or AASHTO M302 Grade level 100 or 120 minimum.

2. Substitution of GGBFS shall be maximum 50% (change per project conditions) by weight of cement. Use of slag shall not increase overall of cementitious content required to meet strength and performance requirements.