

Ground granulated blast furnace slag (GGBS) is manufactured from blast furnace slag, a by-product from the making of iron. The cementitious properties of blast furnace slag were discovered in the late 19th century and it has been widely used in cement manufacture for over 100 years. In the UK, GGBS is supplied as a separate component for concrete and is added at the concrete mixer. It generally replaces between 20 and 80 per cent of the normal Portland cement.

## Production of iron blast furnace slag

The blast furnaces used to make iron operate at temperatures up to 2000°C and are fed with a carefully controlled mixture of iron ore, coke and limestone. The iron ore converts to iron which sinks to the bottom of the furnace. The remaining materials form a slag that floats on top of the iron. The molten iron and slag are drawn off at regular intervals through tapping holes in the base of the furnace. As the slag is drawn off, its chemistry is monitored as a check on the performance of the furnace. This ensures that blast furnace slag is very consistent in chemical composition.

After being tapped from the furnace and separated from the iron, the slag is cooled. The cooling rate of the molten slag determines its physical characteristics. If the material is left to gradually air-cool, it is of no use as a cementitious material and is used as an aggregate. Where the blast furnace slag is to be used for the manufacture of GGBS, it has to be rapidly quenched in water. This process is known as granulation because it produces glassy granules, similar in appearance to a coarse sand. These have excellent cementitious properties.

## Production of GGBS

To produce GGBS, this granulated blast furnace slag is dried and ground to a fineness similar to that of Portland cement. Civil and Marine operates five slag grinding plants, located across England and Wales. Each is a sophisticated production facility, capable of processing up to half a million tonnes a year, to accurately controlled fineness.

## Typical physical properties for Civil and Marine GGBS

Fineness	450 to 550m <sup>2</sup> /kg
Bulk density	1000 to 1100kg/m <sup>3</sup> (loose) 1200 to 1300kg/m <sup>3</sup> (vibrated)
Relative density (specific gravity)	2.9
Colour	Off white

## Typical chemical properties for Civil and Marine GGBS

GGBS contains the same principal oxides as Portland cement, but in slightly different proportions. The following table compares typical percentages of the principal oxides in GGBS with those in Portland cement:

	CaO	SiO <sub>2</sub>	Al <sub>2</sub> O <sub>3</sub>	MgO	Fe <sub>2</sub> O <sub>3</sub>
GGBS	40%	35%	12%	10%	0.2%
Portland cement	65%	20%	5%	1%	2%



# Production and use of GGBS



## Quality control

Throughout the manufacturing process, the physical and chemical properties of GGBS are carefully monitored and controlled. The finished product conforms to either:

- BS 6699, ground granulated blast furnace slag for use with Portland cement<sup>1</sup>
- or the European Standard which will replace it, BS EN 15167-1 Ground granulated blast furnace slag for use in concrete, mortar and grout<sup>2</sup>

These two standards contain similar requirements and generally GGBS that conforms to one would also conform to the other.

## Applications

GGBS is normally used in combination with Portland cement. The GGBS and cement are added into the concrete mixer as separate constituents. Where appropriate, the ratio of GGBS to cement can be varied according to the technical requirements for any particular application. The British Standard for Concrete (BS8500) uses the following notations for specifying the percentage of GGBS as a percentage of the total cementitious content:

Notation	GGBS percentage
CIIA-S	6 to 20% GGBS
CIIB-S	21 to 35% GGBS
CIIIA	36 to 65% GGBS
CIIBB	66 to 80% GGBS

CIIIA is the most widely used combination and is commonplace for ready-mixed, site-mixed and precast concretes in all types of applications. CIIB tends to be used for specialist applications such as those requiring low heat rise or high sulfate resistance. CIIB-S is used for applications such as power-floated floors, mortars, screeds and some precast concrete products that require a relatively high early-age strength. CIIA-S is rarely used.

<sup>1</sup> Due to be withdrawn in May 2008

<sup>2</sup> First published in October 2006



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