

The use of ground granulated blastfurnace slag and pulverized fuel ash in mortar



Introduction

The use of ground granulated blastfurnace slag (ggbS) and pulverized fuel ash (pfa) in mortar has increased in recent years. Records indicate that blastfurnace cement was used for the mortar during the construction of the Empire State Building in the 1930s. Pulverized fuel ash has been used as a constituent material of mortars for over twenty years, and in the case of some of the bagged proprietary mortars for an even longer period.

These materials not only impart technical benefits to both the fresh and hardened properties of mortar they are also environmentally friendly. Both materials are products resulting from industrial processes and their use, therefore, reduces the quantity of primary raw materials that have to be extracted from the ground. Ground granulated blastfurnace slag is classified as a latent hydraulic material. This means that it has inherent cementitious properties, but these have to be activated. The normal means of achieving this is to combine the material with Portland cement. Pulverized fuel ash is classified as a pozzolana. This type of material does not generally have inherent cementitious properties, but if it is combined with a highly alkaline material it forms a cementitious product.

Ground granulated blastfurnace slag (ggbS)

Production

During the manufacture of iron blastfurnace slag, as a co-product, is produced. This material is rapidly cooled to form a granulate and then ground to a fine white powder (ggbS), which has many similar characteristics to Portland cement. When ggbS is blended with Portland cement further recognised cementitious materials such as Portland-slag cement and blastfurnace cement are produced. In the UK, ggbS is manufactured and sold as a separate powder which is then batched and blended within the mixer. It is used extensively in the construction industry to produce concretes, grouts and mortars.

Reaction mechanism

The hydration mechanism of a combination of ggbS and Portland cement is slightly more complex than that of a Portland cement. This reaction involves the activation of the ggbS by alkalis and sulfates to form its own hydration products. Some of these combine with the Portland cement products to form further hydrates which have a pore blocking effect. The result is a hardened cement paste with more of the very small gel pores and fewer of the much larger capillary pores for the same total pore volume. Generally, the rate of strength development is slower than for a Portland cement mortar.

Ggbs Utilisation

Ggbs has been used in mortars for many years, generally in ready-to-use retarded mortars. Increasingly, the dry silo system is coming into use and ggbS is also being used in this method of producing mortar. Typically, ggbS has been used at between 25 and 50% replacement of the Portland cement with or without the addition of lime.

Specification

Factory made cements should normally comply with the requirements of BS EN 197-1 Common cements: CEMII/A-S, CEMII/B-S or CEMIII-A or to the requirements in BS 146 for Type BIIIA. Combinations should comply with the requirements of BS 8500-2:2002:Annex A for Type CII-S or CIIIA.

Use with admixtures

Where retarding admixtures are used to produce ready-to-use retarded mortars the incorporation of ggbs reduces the dosage rate required to achieve the desired level of retardation. The degree of reduction is dependent on the proportion of ggbs used, however, trials indicate that a 35% reduction can be achieved with high proportions of ggbs.

Pigmentation

Ggbs is off-white in colour, which results in the production of a lighter mortar. This has an advantage when incorporating pigments, as the lighter colour results in improved colour depth and a potential reduction in the quantity of pigment required to produce the desired colour. Data indicates that with high proportions of ggbs, pigment dosage may be reduced by approximately 20% without a discernible change in colour as measured by a spectrophotometer.

Efflorescence

The pozzolanic secondary reactions associated with the hydration of ggbs utilise some of the excess calcium hydroxide in the pores and may reduce the risk and extent of any efflorescence.

Pulverized fuel ash (pfa)

Production

Pulverized fuel ash (pfa), or fly ash as it is known in many countries, is a by-product from the burning of pulverized coal in power stations. It has both pozzolanic and physical properties that enhance the performance of mortars. In some parts of Europe natural pozzolanas are available; these are composed of volcanic ashes and their use goes back to Roman times.

Reaction mechanism

Due to the mineralogical composition of the coal used, some pulverized fuel ashes produced within Europe may have latent hydraulic properties in addition to pozzolanic properties. The majority of UK ashes do not.

When Portland cement hydrates it produces alkali calcium hydroxide (lime). Pozzolanas such as pfa can react with this lime to form stable calcium silicate and aluminate hydrates. These hydrates fill the voids within the mortar matrix, thus reducing the permeability and the potential for efflorescence. Additionally, the reduction in the quantity of lime remaining further decreases the occurrence of efflorescence. This process improves the strength, durability, chloride and sulfate resistance of the mortar.

The addition of pfa to a mortar, either as a cementitious material or as an aggregate, normally results in a reduction in the quantity of water required for a given level of consistence. Mortars containing pfa have improved fresh properties, in particular, cohesion and resistance to segregation and bleeding. Furthermore, they will tend to have a slower setting time which is advantageous in warmer weather conditions.

Specification

Typically up to 35% of pfa is permitted, whether in the cement produced at the cement works or blended as an addition at the mixer. Factory made cements should normally comply with BS EN 197-1 (Common cements: CEM II/B-V or BS EN 413-1). Mixer blended cements according to BS 5628-3 should be made with BS 3892-1 pfa and conform to the requirements of BS 8500.

Use with admixtures

Pfa can be used in ready-to-use retarded mortars, however, some adjustment to the air entrainer dosage may have to be made. An allowance may also have to be made to the retarding admixture dosage to take account of the slower setting time.

Pigmentation

Pfa is naturally grey in colour, producing a mortar that appears darker and richer in cement. Its use in lighter, pigmented mortars may, therefore, need special consideration.

Efflorescence

The incorporation of pfa in a mortar assists in the reduction of efflorescence. This is because it reduces the permeability and reacts with some of the free calcium hydroxide as discussed under 'Reaction mechanism' opposite.

References

BS 3892-1:1997	Pulverized fuel ash: Specification for Pulverized fuel ash for use with Portland cement
BS 4721:1981	Specification for ready-mixed building mortars
BS 5838-2:1980	Dry packaged cementitious mixes: Prepacked mortar mixes
BS 5628-3:2002	Code of Practice for use of masonry: Materials and components, design and workmanship
BS 6699:1992	Specification for ground granulated blastfurnace slag for use with Portland cement
BS 8500-2:2002	Concrete - Complementary British Standard to BS EN 206-1
BS EN 197-1:2000	Cement composition, specification and conformity criteria for common cements
BS EN 413-1:2002	Masonry cement: Composition, specifications and conformity criteria
BS EN 450-1	Fly ash for concrete: Definitions, requirements and quality control
BS EN 998-1	Specification for mortar for masonry: Part 1 - Rendering and plastering mortar
BS EN 998-2	Specification for mortar for masonry: Part 2 - Masonry mortar

Note: British Standards are currently being revised in line with European requirements. The new standards are at varying stages of preparation and/or publication, for a full list of British and new European Standards see the MIA data sheet of technical references.



Cement burns (skin ulceration) can result from contact with fresh mortar. Prevent skin contact by wearing suitable protective clothing and eye protection where possibility of splashing exists. Where skin contact occurs either directly or through saturated clothing, wash the affected area without delay. Where eye contact occurs, the area must be immediately and thoroughly irrigated with clean water.

The relevant codes of practice, standards and statutory regulations must always be observed.

The information in this data sheet may be freely copied with acknowledgement to the Mortar Industry Association.



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