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BS EN 450 Fly Ash

Sustainable solutions for construction specialists

October 2014



From left, Leslie WWT plant, Fraserburgh ship lift and Loch Ness, site of the Glendoe hydro-electric project, all have used ScotAsh BS EN 450 fly ash

BS EN 450 fly ash (PFA) is used in projects where strength and durability is fundamentally important, such as the dam at the Glendoe hydro-electric scheme at Loch Ness



Checking another shipment of ash products at ScotAsh

Introduction

The use of Pulverised Fuel Ash (PFA), also known as fly ash, as an addition to concrete results in environmental benefits including conserving primary aggregates, saving water and reducing carbon emissions, while at the same time delivering enhanced performance benefits, including long – term strength gain and durability of the finished structures.

Description

Pulverised Fuel Ash or “fly” ash is the fine ash produced in the furnaces of coal-fired power stations. The ash is a by-product from the combustion of pulverised coal at very high temperatures and pressures.

The ash is a mineral rich substance that cools and solidifies into rounded glassy particles in the flue gases, which are carried upwards and captured by electrostatic precipitators.

The PFA particles are mostly extremely fine, glassy spheres that are similar to cement in appearance. BS EN 450 is a harmonised European Standard for fly ash that replaced the former British Standard BS 3892: Part 1 in January 2007.

Quality Assurance

ScotAsh products are manufactured under a Quality Management System (QMS) that complies with the requirements of BS EN ISO: 9001.

The QMS is registered with and audited by BSI. Our BS EN 450 fly ash product carries the CE mark.

BS EN 450 Fly Ash

Specification

Three categories of fly ash are permitted under BS EN 450:

- Category A: LOI not more than 5.0%
- Category B: LOI 2.0% to 7.0% and
- Category C: LOI 4.0 to 9.0%

ScotAsh does not produce Category C fly ash, which is not permitted in UK concrete, as the LOI upper limit under BS 8500 is 7.0%.

There are two categories for fineness:

- Category N: not more than 40% retained on the 45 microns sieve and a limit of + 10% on the supplier's declared mean value permitted
- Category S: not more than 12% retained on the 45 microns sieve

ScotAsh produces Category N fly ash only. The table (right) outlines the main requirements of the standard and the typical values for ScotAsh material.

Property	Typical ScotAsh results	BS EN 450 requirements	
		Lower limit	Upper limit
Loss of Ignition (%)	2.1-4.0		5.0
Fineness on 45mm (%)	12.5-18.0	5.0	25.0
Sulfuric anhydride as SO ₃ (%)	0.22-0.69		3.0
Particle Density (kg/m ³)	2090-2120		
Soundness (mm)	0.5		10.0
Chlorides (%)	<0.010		0.10
Reactive Calcium Oxide (%)	1.26-3.9		10.0
Activity Index (%) 28 Day	78-82	75	
Activity Index (%) 90 Day	92-95	85	

Selection

BS EN 450 Fly Ash is specially selected at ScottishPower's Longannet Power Station.

'Real Time' Carbon analysers monitor the Loss-on-ignition of the PFA as it is carried out in the flue gases to ensure that material of not more than 5% carbon is selected for sale.

The 'fly ash' particles resemble cement in appearance and are very similar chemically, containing the same basic oxides in differing proportions and mineralogy.

Moreover they demonstrate pozzolanic properties in concrete, i.e. the 'fly ash' has the ability to react with the lime released by hydrating Portland cement to produce cementitious hydrates. BS EN 450, when used correctly, offers many benefits to both the placing and finishing of concrete and concrete products.



Electrostatic separation enables us to control the carbon content of the ash

Fresh Concrete Properties

The physical characteristics of PFA offer several key advantages when it is used in concrete.

The spherical, ultrafine particles result in improved rheology, reduced bleeding and help to reduce the water requirement, making the concrete more thixotropic.

The concrete mix will appear drier than ordinary Portland cement concrete and care should be taken during mixing to guard against excess water use.

Concretes containing PFA have greater pumpability and often it is possible to pump mixes directly without altering the fine aggregate proportion.

Bleeding of concrete can be a problem with conventional mixes, often due to the lack of suitably graded sands.

When PFA is used the higher fine material content and reduced water demand results in a more cohesive mix that is less prone to segregation and bleeding.

BS EN 450 Fly Ash

Applications

Pulverised Fuel Ash (PFA), or 'fly ash' as it is known, has both pozzolanic and physical properties that enhance the performance of concrete. The reaction between the free lime from the hydrating Portland cement and the fly ash improves the strength, durability, chloride and sulfate resistance of concrete.

The advantages of using fly ash in concrete can be summarised as follows:

- Improves long term strength performance and durability
- Reduces permeability, which reduces shrinkage, creep and gives greater resistance to chloride ingress and sulfate attack
- Minimises the risk of alkali silica reaction
- Reduces the temperature rise in thick sections
- Makes more cohesive concrete that has reduced rate of bleeding, is easier to compact, gives better pumping properties and improves the finish of the struck concrete

Utilising the properties of fly ash makes it particularly advantageous for the following applications:

- For use with alkali-reactive aggregate
- Mass concrete sections
- Effluent treatment plants
- Marine environment
- Pumped concrete
- High quality finishes
- Sulfate-bearing environments
- Chloride-bearing environments
- Water retaining structures
- Self compacting concrete
- Concrete products & precast operations

It also gives satisfactory results:

- For air entrained concrete
- For thin sections
- For cold weather

However, it can be used only with care in high early strength applications unless hydration is accelerated by increasing the temperature.

For general purpose applications, concrete containing between 25% and 40% BS EN 450 is most suitable. The



Leslie WWT works (above and below) under construction in Fife



Mix Design

Concrete can be mixed simply by replacing a proportion of the Portland cement with the same amount of PFA, although this may lead to a slight reduction in the early strength.

Alternatively, the mix can be designed to achieve a specific strength at a particular time. ScotAsh is happy to provide advice on the mix design to any customer on request. Normal admixtures can be used in concrete containing PFA, though some manufacturers offer admixtures that are designed specifically to work with the finer particle size of PFA.

exact proportion of PFA used in the mix for optimum results will depend on other factors such as:

- Cement content
- Placing method
- Strength requirements
- Durability requirements

Where long term durability is an essential requirement, a minimum PFA content of at least 30% by weight of the cementitious content is often specified.



Hardened Concrete Properties

Strength Development

The typical strength development of concrete containing PFA is illustrated (top), where both mixes have been designed for equal 28-day strength.

There is a marginal decrease in early strength development up to seven days, which can be exacerbated in cold weather. After 28 days, the PFA concrete continues to increase in strength due to the pozzolanic properties of PFA.

External factors affecting strength gain includes ambient temperature, which is illustrated (centre).

Heat of Hydration

One of the main uses for concretes containing PFA is the control of the heat of hydration. Reductions in heat generated can be in the order of 20-30% (illustrated below, right).

Drying Shrinkage

It has been demonstrated that the use of PFA in concrete can reduce shrinkage by up to 80%.

Creep

Creep is significantly less than Portland cement concretes as PFA concrete continues to gain strength with time.

Durability

The durability performance of PFA based concretes matches or exceeds that of plain Portland cement concrete.

Generally, concretes containing PFA show significantly improved durability characteristics when used correctly.

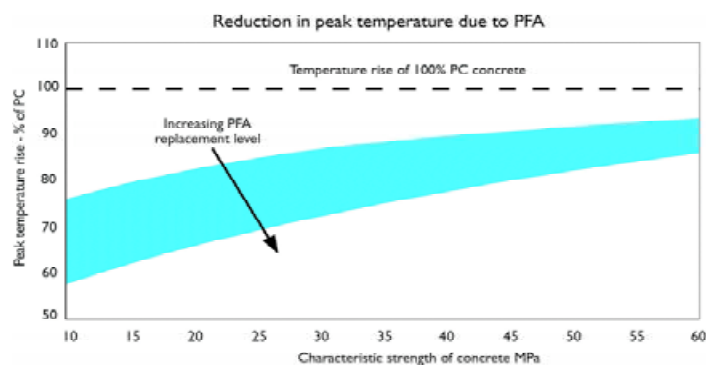
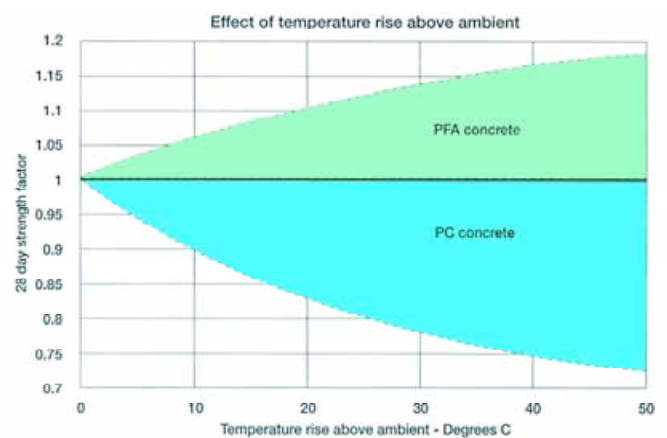
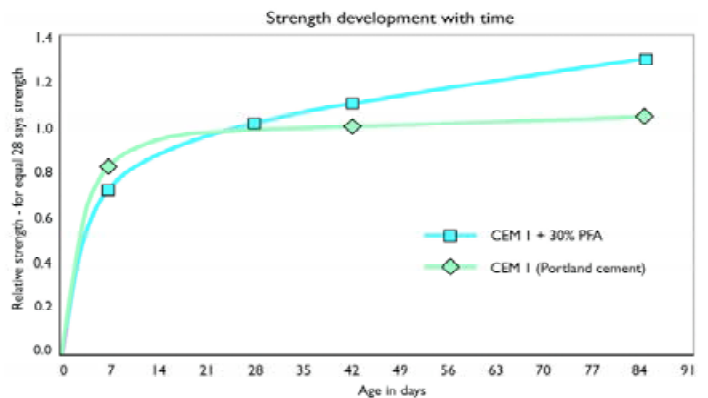
In addition, they are resistant to chemical attack, including:

- **Sulfate Resistance (including Thaumassite Sulfate Attack):** Concretes containing PFA are allowed in all classes of sulfate conditions, apart from DC-4m
- **Chloride Ingress:** Correct use of PFA in concrete can reduce chloride ingress by up to 90%
- **Alkali-silica Reaction:** PFA in concrete reduces the risk of ASR where aggregates cannot be classified as non-reactive. See guidelines issued by the Concrete Society and BRE or contact ScotAsh for details. The resistance of PFA based concretes to sulfate attack and chloride ingress make it particularly suitable for use in marine environments.

Colour and Finish

Generally concretes containing PFA tend to be slightly darker than Portland cement concretes, although PFA concretes can be colour treated.

If concretes containing differing amounts of PFA are to be used in adjacent sections, or alongside concrete containing only Portland cement, consideration should be given to the aesthetics as there may be visible differences in colour. It is widely



acknowledged that concretes containing PFA provide an aesthetically superior finish to conventional PC concretes.

Health & Safety

PFA is not considered to be hazardous to health, but it should be handled in accordance with good occupational hygiene and safety practices. High concentrations of dust may cause irritation.

It is recommended that Personal Protective Equipment including eye protection, hand and skin protection and dust masks are worn when handling this product. For further information see the Health and Safety information sheet for PFA.

To contact ScotAsh please telephone, fax or visit our website

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