UNITED KINGDOM QUALITY ASH ASSOCIATION

TECHNICAL DATA SHEET

Pulverised Fuel Ash for grouting

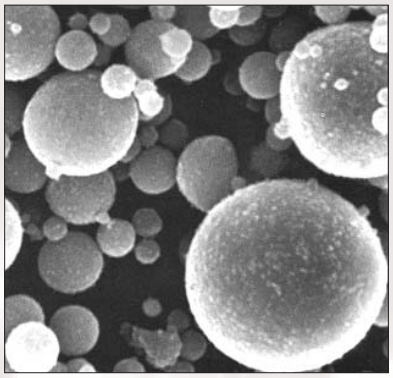
Introduction

Grouting is required when inaccessible voids require filling to improve ground stability, increase the shearing resistance, strength and reduce the permeability. This is normally achieved by injecting suspensions, emulsions and solutions into the ground to improve the geotechnical properties of the soils and rocks. PFA grouts are suspension compositions produced on site, normally using PFA, Portland cement and water. PFA has been used for many years as an alternative to sand and cement grouts because of the technical, rheological, durability and economic advantages if offers.

The benefits of using PFA for grouting

The advantages of using PFA grouts over sand cement grouts are:

- Reduced bleeding.
- Extended working life.
- Excellent pumpability and flow characteristics.
- Reduced permeability.
- Increasing compressive strength and durability with time.
- Increased yield per tonne.
- Reduced water/solids ratio.
- Economy.



Spherical PFA particles

Properties of PFA for grouting

Particle shape

PFA consists of spherical particles, with sizes ranging predominately from 1µm to 150µm as shown in Figure 1. The forms of PFA used for grouting are dry, conditioned and lagoon PFA - the latter generally being somewhat coarser. These form a continuous grading as shown which imparts the excellent rheological properties to PFA grouts.

Composition

PFA is essentially silica, alumina, calcium and iron oxides as shown in Figure 2. However, the oxide composition does vary with source and more precise data are available upon request from the supplier.

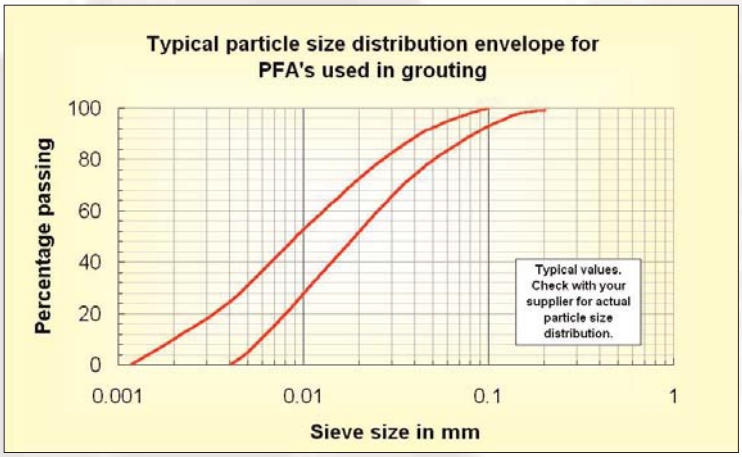


Figure 1 - Indicative grading values

Particle density

The lower particle density of PFA can be an advantage. The average particle density for PFA is 2.15 whereas typically cement is 3.12 and sand 2.70. The bulk density of PFA grout is typically 1500 to 1800kg/m^3. This produces a grout with a significantly lower density than PC:Sand grout that can be beneficial where weight is an important factor.

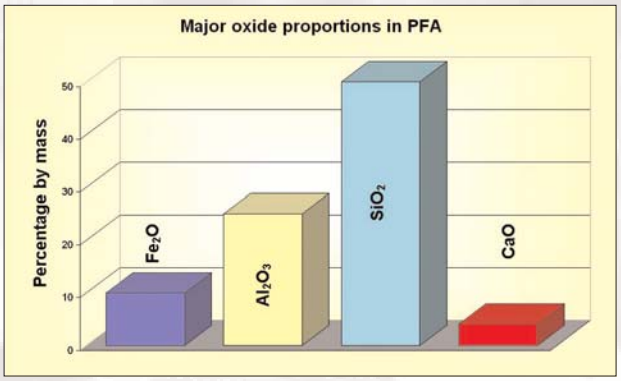


Figure 2 - PFA is silica, alumina, iron and calcium oxides


Drilling rig

Types of PFA grouts

There is a diverse range of grouts available:

- **PFA only grout** - A low strength grout only used for filling cavities. Water solids ratios are typically between 0.35 and 0.50. Strengths are very low and the grout may remain soft for a long period of time if water is not able to drain away.
- **PFA/Cement grout** - By varying the PFA cement ratio various strengths and densities can be achieved. The ratios of PFA to PC vary from 1:1 to 20:1 depending on the strength and elastic properties required.
- **PFA/Lime grout** - The addition of lime promotes pozzolanic activity to improve the strength of the set grout. Lime also improves the pumpability. However, as lime and cement are similar in price there is little advantage in using lime over Portland Cement.
- **PFA/Cement/Sand grout** - Sand and even gravel can be added to grouts where the particle size is not critical. The density of the grout is increased.
- **Specialist grouts** - Specialist grouts are usually factory blended and modified to suit the user's particular need. They contain additives such as accelerators, retarders, etc. or, where a more cohesive grout is required, bentonite. PFA grouts can be formulated to provide any normally specified rheological properties, including thixotropy, viscosity, density and gel time.

PFA : Cement by weight	Quantities in kg to produce 1m³ of grout			Bulk density kg/m³	Typical compressive strength at 28 days N/mm²
	PFA	PC	Water		
1:4	285	1140	500	1925	20 - 30
1:3	355	1065	500	1920	
1:2	465	930	490	1885	
1:1	675	675	475	1825	
2:1	870	435	455	1760	4 - 13
3:1	965	320	450	1735	
4:1	1020	255	445	1720	
5:1	1055	210	445	1710	
6:1	1080	180	440	1700	2 - 4
7:1	1100	155	440	1695	
8:1	1115	140	440	1695	
9:1	1125	125	440	1695	
10:1	1135	115	440	1680	
11:1	1140	105	435	1680	< 2
12:1	1150	96	435	1680	
13:1	1155	90	435	1680	
14:1	1160	85	435	1680	
15:1	1165	80	435	1680	

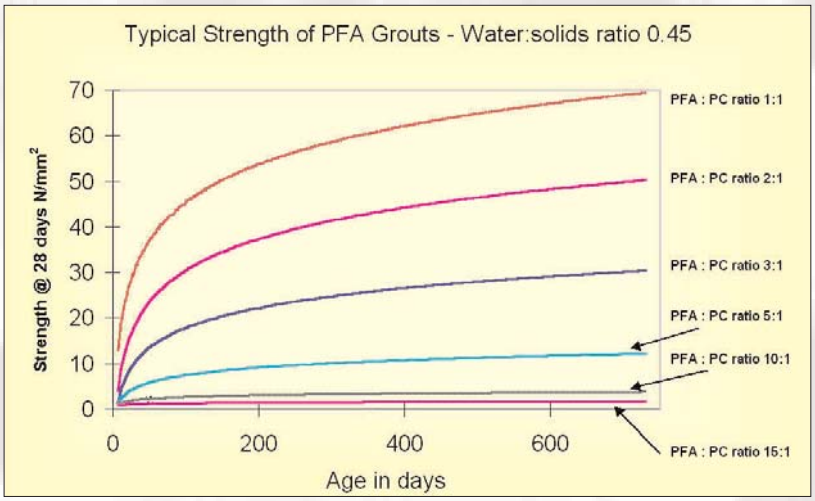


Figure 3 - Strength development in PFA:PC grouts

Supply of PFA for grouts

PFA can be supplied dry, either in bulk or in bags, or in a conditioned form, i.e. with a measured amount of water to assist with handling and reduce the risk of creating a dust problem. Lagoon PFA is material that has been sluiced to lagoons. This is allowed to drain and the PFA is subsequently recovered. Conditioned and lagoon PFA are normally stored on site in a simple ground bay or in a heap. If the rate of usage can justify a silo then dry PFA can be supplied in tankers.

Material requirements

The table above gives typical batch weights and approximate strengths for various PFA grouts. Variations in these values will occur depending on local conditions and the cement used.

Properties of PFA grouts

Flow properties

Grout workability is normally measured by a viscometer assuming Bingham fluid characteristics. PFA, because of the nature of its particle shape and size distribution, improves both the yield stress (τ) and viscosity (μ) values. Empirical data from the Colcrete flowmeter or Marsh Cone show that PFA grouts with a flow value of 450mm or above provide a grout of sufficient pumpability for most situations.

Bleeding

PFA improves the stability of grout suspensions as shown in Figure 5. This is not only due to the lower relative density of PFA but also its ability to attract and retain water on the particle surface.

Setting time

PFA grout tends to have a slower setting time than Portland Cement sand grout. The overall strength development can, for practical purposes, be considered similar, although at very high PFA contents this is at a slightly slower rate.

PFA grouts retain their workability for longer periods after mixing than PC only grouts as shown in Figure 4.

Strength properties

PFA is a pozzolana, which reacts with lime to form complex calcium silicate hydrates that contribute to strength. The lime can either be added as hydrated lime or from the lime produced as a by-product of the Portland cement reaction with water. The reaction occurs over an extended period of time as shown in Figure 3.

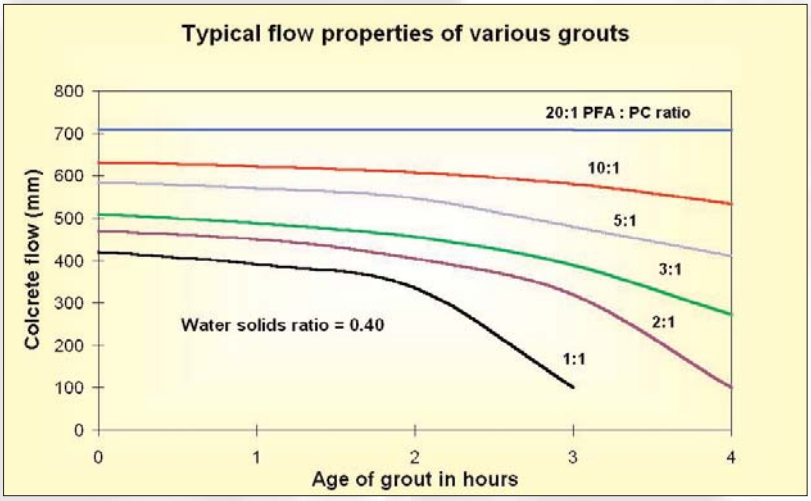


Figure 4 - PFA grouts retain their workability well

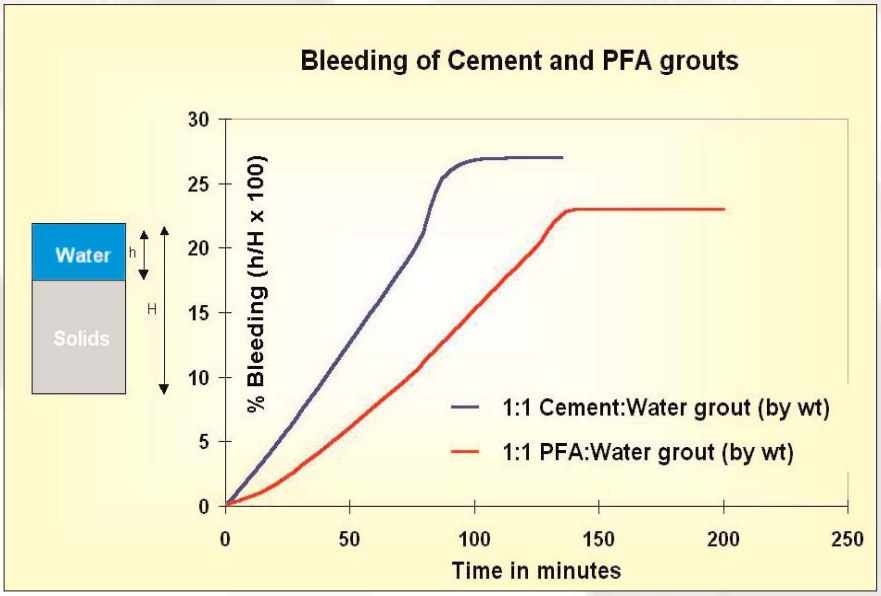


Figure 5 - PFA reduces bleeding

Admixtures

The performance of PFA grout can be extended by the use of admixtures. These are often specially formulated for grouts to control setting, prevent washout, and to improve flow and pumpability characteristics. Retarders, air entrainers and plasticisers are all regularly used with PFA grouts. PFA grouts can be modified to produce no shrink and non-dispersing properties.

Durability

In some circumstances grouts may come into contact with sulphates, e.g. in some clay soils, contaminated ground, old mine workings, etc. The use of PFA with Portland Cement is normally satisfactory for sulphate resistance. The use of SRPC offers no additional benefits. PFA reduces the permeability because of the particle size, shape and the pozzolanic reaction. In addition shrinkage is significantly reduced when compared to Portland cement only grouts. For the details and requirements on the use of PFA in ground conditions containing sulphates detailed guidance is given in BRE Special Digest 1.

Pulverised fuel ash (PFA), or fly ash as it is known in many countries, has both pozzolanic and physical properties that enhance the performance of concrete. When Portland cement hydrates it produces quantities of alkali calcium hydroxide (lime). Pozzolanas like PFA react with this lime to form stable calcium silicate and aluminate hydrates. These hydrates fill the voids within the concrete, removing some of the lime and thus reducing the permeability. This process improves the strength, durability, chloride and sulfate resistance of the concrete. The pozzolanic reaction occurs relatively slowly at normal temperatures enhancing strength in the longer term relative to normal Portland Cement concrete.

The finer fraction of PFA, i.e. those particles that pass the 45µm sieve, act as a solid particulate plasticiser. These particles are spherical and act like ball bearings within the concrete reducing the water requirement for a given workability. A reduction in the water content lowers the permeability and increases strength and durability.

Grout injection point

In general usage the term ‘fly ash’ is used for pulverized coal ash but it can also cover ash from burning other materials. Such ‘fly ash’ may have significantly differing properties and may not offer the same advantages as ash from burning pulverized coal. UKQAA datasheets only refer to PFA / fly ash produced from the burning of predominantly coal in power stations.