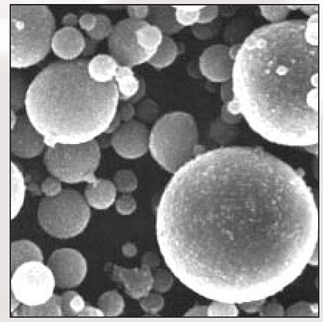
UNITED KINGDOM
QUALITY ASH
ASSOCIATION

TECHNICAL DATA SHEET 2

Pulverised fuel ash for fill applications

Introduction



There are a considerable number of advantages in using pulverised fuel ash (PFA) or fly ash[1], as it is known in many countries, as a fill material over naturally occurring materials as follows. PFA is beneficial for the following reasons:

- It is lightweight when compared to most materials, as shown in figure 1. This leads to savings in material, transport costs and reduces settlement in underlying soils.
- When properly compacted, PFA settles less than 1% during the construction period with no long-term settlement.
- The self-hardening properties of some PFA's offer considerable strength advantages over natural clay and granular materials.
- They can exceed the design strength immediately after compaction.
- The immediate strength of PFA means simple shallow trenches have a reduced need for shoring.
- With proper profiling PFA fill can be trafficked in all weathers.

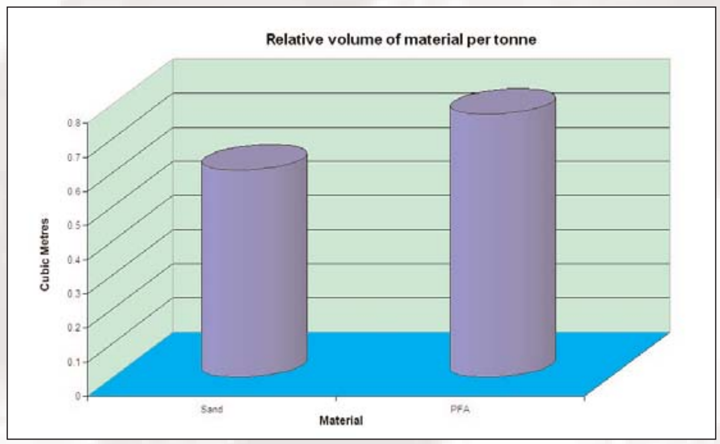


Figure 1 - PFA is lightweight and economical

The types of PFA available

There are three types of PFA readily available for use as a fill material:

- **Conditioned ash** - PFA taken directly from the silos at the power station to which a controlled amount of water is added to assist in handling, dust prevention and compaction on site.
- **Stockpiled ash** - Previously conditioned PFA that has been stockpiled prior to use.
- **Lagoon Ash** - PFA which has been slurried and pumped to storage lagoons. It is then allowed to settle and drain before delivery. Lagoon ash can be somewhat more variable in particle size distribution than conditioned ash.

The Properties of PFA

PFA is usually placed in accordance with the Manual of Contract Documents for Highway Works, Volume 1, Specification for Highway Works (SHW) that classifies it as a cohesive material for general fill (type 2E), as a structural fill (type 7B) or for stabilisation with cement (type 7G) to form capping (Class 9C). All PFA is suitable for general fill but only freshly conditioned PFA is considered by the SHW as being suitable for structural fill (7B) or capping (7G). This is considered to be restrictive and preferably it should be specified in terms of its properties and not type.

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[1] 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.

The following information is based on typical values and provided for guidance only. The actual values for any source can be obtained by contacting the supplier.

Optimum moisture content

The moisture content of PFA is an important factor in achieving the desired compaction and density values. The optimum moisture content varies from source to source as in figure 2. In practice sufficient compaction can be achieved over a range of moisture contents between 0.8 and 1.2 times the optimum value.

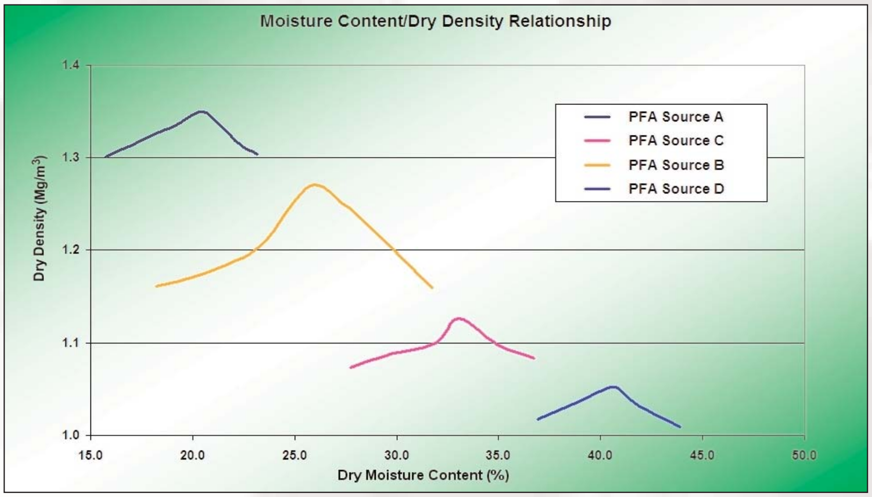

Figure 2 - Typical maximum dry density and moisture content relationship for PFA from various sources

Though the supplier adds water to PFA some variation in moisture content will occur especially during hot weather or when the PFA has been stockpiled on site prior to placing. It is recommended that provision be made to add water on site at the time of placing.

Strength - PFA is defined as a cohesive material, with the shear strength increasing with time with most ashes. PFA is placed in a partially saturated condition but may become saturated at later stages, which will reduce the measured strength. Therefore, it is important that all strength tests are carried out on saturated samples. Strength can be measured in many ways:

- The SHW requires peak shear parameters based on saturated shear box tests. The proposed values are: c'_{peak} = 5 kPa and ϕ'_{peak} = 30°. However, it is recommended that guidance on the actual values be sought.
- CBR is often used in road design. CBR values tend to rise with time increasing the factor of safety.
- Design is normally based on strength at zero days. Typical low bound values for inundated ash at zero days are:
    - ⇨ Peak shear cohesion - 0 kPa to 20 kPa
    - ⇨ Peak shear friction angle - 26° to 35°
    - ⇨ Critical state - c'_{crit} = 0, ϕ'_{crit} = 26° to 30°
    - ⇨ CBR - 10% to 20%

Stiffness - Providing the PFA has been adequately compacted there are no long-term settlement problems. Even poorly compacted PFA has been shown not to settle to any significant extent. Any settlement will occur during construction. The m_v value is typically 0.1 to 0.4 m^2/MN.

Air voids - PFA has a higher air voids content than conventional fill materials. Typically air contents range from 8 to 20%. Consequently, the use of maximum air voids limits may not be appropriate.

Permeability - Even though PFA has a relatively high air content it can be considered comparatively impermeable; typical k values are:

$$2 \times 10^{-5} \text{ to } 3 \times 10^{-7} \text{ m/s}$$

Normal rainfall may be held in the air voids without saturation occurring. If the PFA does become saturated then it will soon recover if left. The low permeability prevents leaching of soluble material from the mass of the compacted material.


Figure 3 - Compacting PFA on the Selby by-pass

Frost Heave - Water may rise by capillary action in PFA even after compaction. A drainage layer of coarse free draining material 150 - 450mm in depth should be placed below the PFA to eliminate capillary action. This may consist of Class 6D materials in Table 6/1 of the SHW, Furnace Bottom Ash, free draining stone or a geotextile membrane. The capillary action does make PFA, like all fine-grained silts and clays, frost susceptible when saturated. Lagoon ash and stockpiled PFA mixed with a coarser material are only slightly frost susceptible, if at all.

Sulfate content - The SHW requires the sulfate content of the PFA to be measured to TRL report 447 for Type 7G capping applications only. The Water Soluble sulfate content (WS), the Oxidisable Sulfides content (OS) and total potential sulfate (TPS) values are required.

The sulfate content of conditioned PFA, based on a 2:1 water extraction, averages 1500mg/l and rarely exceeds 2400mg/l and is even lower in lagoon PFA. The total sulfate of conditioned PFA averages 0.83%. The sulfate in PFA is mainly present as calcium sulfate, which has limited solubility and there are lesser amounts of sodium and potassium sulfate. The water soluble magnesium content of PFA is very small. Since PFA is produced in a high temperature environment, all sulfur is present as sulfate and therefore there is no sulphide or pyrites present to oxidise to sulfate.

The sulfate levels mean that PFA should not be placed within 500mm of concrete, cementitious bound materials or metallic items forming part of the permanent works. There has been no reported incident of sulfate attack on adjacent concrete structures, even after 25 years exposure. PFA would normally be categorised as a DS 2 or 3 to BRE Special Digest 1 and BS8500 Table A.2. However, the sulfate is mainly present as gypsum, which has a limited solubility.

The pH of conditioned PFA is variable depending on coal source, but is typically 9 to 11. The pH of lagoon PFA is generally around 9.

Environmental aspects - PFA has less than 1% water soluble materials, most of which is gypsum. However, the presence of trace elements can result in high alkalinity and some minor compounds may not be considered acceptable in areas where highly sensitive aquifers are nearby. Exposed PFA may be prone to dust issues and wash out if not properly designed with suitable falls for drainage and protection from drying out.

PFA has been used as a fill material in the UK for over 50 years and in that time, to our knowledge, there have never been any major environmental incidents. However, as with other materials care must be taken to ensure that the environment is protected and guidance can be found in the 'Environmental Code of Practice for Fill' available from the UKQAA website.

PFA will not support plant growth because of a lack of nitrogen. A PFA embankment should always be covered in some manner, either with the construction, by hydro-seeding or a layer of top soil. If top soil is used a minimum thickness of 100mm is recommended, though up to 0.5m of soil may be required in some environmentally sensitive locations. Pockets of soil/growing medium may be required to establish trees in a PFA embankment. Further information on plants species that will grow in PFA can be obtained from the UKQAA.

Compaction - PFA fill is normally placed in layers of up to 225mm thick compacted down to 150mm. Widely available compacting plant can be used - see our Best Practice Guide No.2. Typically 6 - 8 passes is sufficient to fully compact each layer. Though the Specification for Highway Works (SHW) requires at least 95% of the maximum dry density, historically 90% has been accepted by many sites as being satisfactory. This has been confirmed by research, providing the moisture content is less than the optimum value.

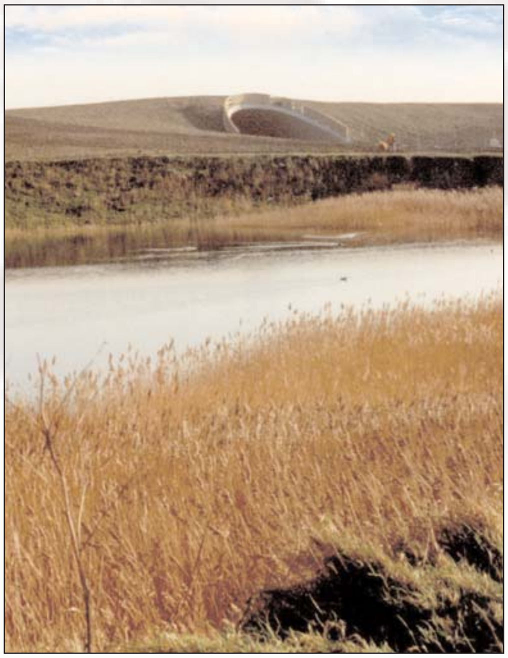

Figure 4 - PFA was used to landscape and form the access via a bridge at the Llanelli Millennium Coastal Park, Wales

The maximum dry density and optimum moisture content should be determined using the 2.5kg rammer as described in BS1377 Part 4. As with any fill material there is some variability in the maximum dry density of PFA from a given source and regular testing is required.

Site Operations

As with all site operations careful planning will pay dividends. We would recommend the following:

- PFA should be delivered in sheeted vehicles to prevent moisture loss and environmental problems.
- Spread the PFA in loose layers not exceeding 225mm thick.
- Compaction is normally achieved by a towed or self-propelled vibratory roller or pneumatic-tyred rollers. Six to eight passes are normally required.
- If water is to be added this should be sprayed uniformly over the surface before compaction. Back tining may be used to encourage an even distribution throughout the full depth of the layer. A water bowser is the most suitable means of obtaining a uniform distribution.
- The surface must be finished to a fall to ensure adequate surface drainage.
- If end product control is used then density tests should be carried out on the penultimate layer. The test rate is usually 1 test per 200m^3 (1350m^2 for 150mm thick layers) for small projects and 1 test per 500m^3 (3500m^2 for 150mm layers) for larger projects.
- If PFA is stockpiled on site care must be taken to prevent drying out.
- If one fails to achieve the density criteria the tests should be repeated and the maximum dry density checked. The 2.5kg rammer should be used.
- If the surface becomes wet due to heavy rain the surface should be allowed to dry out, or if necessary the top 150mm can be removed and replaced. The removed material may be reused when it has dried out sufficiently.

Site Testing - Measurement of density can be made using core cutter equipment. However, in some instances the PFA can become so stiff it is difficult to drive the mould in without disturbing the sample. If this occurs the sand replacement method should be used. Nuclear density techniques have been used but care must be taken in determining moisture contents.

Other applications

Cement or lime stabilised PFA - PFA can be used in stabilised capping as type 9G in Table 6/1 of the SHW using class 7G selected PFA. In addition, road bases, sub-bases and hard shoulders can be constructed using cement or lime stabilisation. See our 6 series datasheets for further information on Fly Ash Bound Mixtures (FABM).

Landscaping - PFA has been widely used for landscaping derelict areas. It will support, with modest encouragement, a variety of vegetation. Methods of establishing cover range from hydro-seeding to applying topsoil or subsoil. An application of fertiliser or a first sowing of clover or other suitable crop will redress the deficiencies in nitrogen and organic matter.

Remediation of contaminated ground - PFA being a low permeability, pozzolanic material can be used to contain contaminants in brown field sites thus preventing leaching from contaminated waste.