Practical Recommendations for the use of Pulverised Fuel Ash as an Engineering Fill in the UK

Ian Fox[1], Bob Coombs[1]

[1]RWE NPower, Windmill Hill Business Park, Swindon, UK , SN5 6PB

KEYWORDS: Engineering Fill, Risk Assessment, Environmental, Utilisation, Method Statement, Source, Receptor, Pathway, Health & Safety

INTRODUCTION

For many years Pulverised Fuel Ash (also known in the UK as PFA and in many countries as coal fly ash) has been used as an engineering fill material. Over the period there have been many changes in the requirements for the approval for its use. Initially the main considerations were related to the engineering properties, but there have been increasing legislative pressures that have led to tighter regulation, imposed primarily to protect health and the environment.

This paper sets out to discuss legislative, health & safety and corporate responsibility requirements and issues related to the supply of PFA to large scale engineering fill applications. By way of a practical example the project to supply 160kte of PFA to the Celtic Manor resort in South Wales is discussed. Details describing the measures taken to mitigate against the impact on health, safety and the environment during the import phase of PFA and after construction will be discussed.

The paper is intended to provide a practical user guide to parties in the process of. or planning large future movements of PFA. Details of how to place and compact PFA to achieve optimum performance in terms of strength once in situ are well documented and will not be discussed in this paper.

HISTORY

PFA has a long history of being utilised as an engineering fill material in the UK, first recorded in 1952. Its use was not covered by legislation other than that employed to ensure safe and appropriate handling and placement.

Current legislative controls arise mainly from European Directives which have subsequently been adopted into UK law. The directives relevant to the use of PFA as a fill are the Waste Framework Directive (75/442/EEC,superseded by 2008/98EC) and the Groundwater Directive (80/68/EEC superseded by 2006/118/EC). These, along with UK regulations and guidance documents, set out the requirements for an assessment of a construction project using recovered wastes; the Environment Agency (EA) deem that PFA is a waste and that it is covered by the waste regulations; the European Waste Catalogue considers PFA to be a non-hazardous waste. The consequence of this is that there is a duty of care on the producer to ensure that the waste is treated in the correct manner and that the movement of it is controlled and traceable. Furthermore, an exemption to the regulations has to be sought from the EA before PFA (or any waste) can be used as an engineering fill in construction. PFA consequently suffered from the denigration and a subsequent reduction of its utilisation as a fill material.

Currently the EA are undergoing a review to create a mechanism, via a Quality Protocol, where it can be considered as a product rather than a waste. The Protocol includes guidance on where the use of PFA is not acceptable because of the potential for polluting potable groundwater.

Whatever the state of prevailing legislation, as companies with an inherent Corporate Responsibility, it is incumbent on the Electricity Generators to ensure that the necessary steps and procedures are put in place to protect the environment and population from the risk of adverse effects of our activities.

CELTIC MANOR SITE

A good example of a site to demonstrate how RWE Npower managed the supply of 160kte of PFA for use as a fill material is the Celtic Manor Resort.

Situated near Newport in South Wales, Celtic Manor is a five star resort which includes a championship standard golf course and will host the Ryder Cup golf competition in 2010. The Ryder Cup is one of the World's premiere sporting tournaments and Celtic Manor is making significant investments to prepare the venue. These improvements include the construction of the new 2010 Club House, extensive media centre, practice ground and the championship golf course itself, enabling it to meet the needs of the world's top golfers, the media and thousands of visitors from across the UK, Europe and America.

To create the practice facilities the challenge was to raise the ground level across a wide area by from between one to three metres, depending on existing contours and required finished levels. This was designed to provide protection from flooding due to the close proximity of the river Usk which borders the area on a number of sides and is tidal in nature.

The river banks were bunded at their boundaries with the site and clay was used to construct the bunds.

USE OF PFA

The site was already importing inert materials consisting of topsoil, sub soils and arisings from other construction projects in the vicinity. The necessary legislative and regulatory permissions were in place to accept these materials on the site. However, there was insufficient inert materials available locally to complete the works in the time available.

RWE proposed the use of PFA from Aberthaw power station to the site owners and managers as a suitable fill material. There were a number of factors to commend the serious consideration of PFA, including but not restricted to:

- The material was available on a stockpile at Aberthaw Power Station in sufficient quantities.
- The material could be tested and consistency could be assured.
- Celtic Manor is relatively local to Aberthaw Power Station (34 miles)
- Being lightweight, PFA was more cost effective to transport than soils
- The Engineering properties of PFA can be confirmed and substantiated after many years of successful relevant utilisation.
- The use of PFA is cost effective

Because the Quality Protocol was not in place at the time, an exemption to waste regulations had to be sought. One of the requirements for this is an environmental impact assessment (EIA) to ensure that the use of PFA, which is classed as non-hazardous and not inert, does not affect the environment nor is it a threat to human health. The EA were consulted and suggested that a risk assessment carried out in accordance with the "Environmental Code of Practice – Stabilising mine workings with pfa grouts" (BRE 2006). Although the Celtic Manor did not require grouting (injection of a cement/pfa slurry into the ground to improve strength), the methodology in the risk assessment was felt to be appropriate. The EIA was carried out using the company resources; RWE npower has this capability and can call on the resources of 50 environmentalists and engineers.

IMPLEMENTATION

The risk assessment adopts the source/pathway/receptor analysis as detailed below. The source is the potential source of pollution, the source is either surface water or ground water that may be polluted by the source and the pathway is the means by which any pollution may migrate from the source to the pathway.

TAKING EACH IN TURN

SOURCE

The proposed utilisation is outlined, giving details of where the material will be sourced from, how the material will be placed, along with total tonnages. A brief description of the physical characteristics of the material is given, including permeability, supplemented by a full chemical analysis detailing the solid phase and leachate analyses.

Using this analysis, a comparison is made for each element, maximum and mean concentrations, against UK Drinking Water Standard (DWS). This process accurately identifies the areas that represent a risk in this particular application. Not only does this process identify the risk, but it also indicates the extent by which the elements exceed or fall within the standard.

PATHWAY

Starting point for this information was 1:50,000 Geological data obtained from British Geological Society (BGS). This gave details across the site indicating the sub strata compositions. This source indicated that the site was underlain by tidal flat superficial deposits commonly comprising clay and silt (alluval deposits) with a low permability. Beneath the alluvial deposits lies the bedrock comprising interbedded layers of mudstone and sandstones.

A previous borehole investigation close to the site confirmed this general understanding and further confirmed that the alluvial deposits extended to a depth of at least 7m below ground level.

RECEPTOR

Next stage was to refer to EA groundwater vulnerability map (1:100,000), this indicated that the formation in the area was designated as a variably permeable minor aquifer. Furthermore during the previous borehole investigation, the groundwater rose to an increased height at the site of investigation, indicating that the groundwater was under positive (variable) pressure. The significance of this being that any movement of water out of the infill would not find its way into the bedrock (and aquifer).

The aquifer, was identified as the most vulnerable feature assessed in terms of risks associated with the SOURCE and PATHWAY. It was identified that the site was not located within a groundwater protection zone and was brackish and medium to poor quality. The significance of this element of investigation is to determine how sensitive the specific ground water is in terms of abstraction.

Having identified, and wherever possible quantified the site specific elements of the site as described, this enabled a RISK ASSESSMENT to be carried out.

ENVIRONMENTAL RISK ASSESSMENT

Each element of the above data was ascribed a score with an associated reasoning, results contained in table below, the risk factors being taken from the BRE document. The scores were then each multiplied with each other, this method allows an empirical value to be obtained. The scale is from 0 to 100, thereby showing the significance of risk for this particular site.

Preliminary risk assessment values

	Score	Reasoning
Source	2	The size of the area to be filled is greater than 250 m^3 and the PFA materials classification is III, with no List 1 substances and peak leachate concentration in column tests is < 20 times UK DWS.
Pathway	1	The site overlies a minor aquifer with variable permeability which is protected by a layer of superficial deposits >7 m which will attenuate any leakage of contaminants.
Receptor	4	The site is not located within a groundwater source protection zone and the groundwater quality is likely to be of medium quality.
Indicative Risk Factor = 2 x 1 x 4 = 8		

The low score in the assessment indicates that there is little risk of pollution of the aquifer by placing PFA on the site. Further commentary on the site identified that the PFA, due to its pozzolanic properties and low permeability would not produce any significant quantity of leachate, furthermore, the composition of the site being overlain with at least seven metres of low permeability alluvial deposits, combined with positive pressure in the aquifer meant that ‘there is no significant risk of pollution of groundwater at the site.’

The above findings were presented to the EA in a formal report format along with a request to confirm acceptance of an exemption to allow import of PFA to the site within predetermined quantities, timescales and areas. The EA accepted the finding and granted the exemption.

ASSESSMENT OF PROJECT LOGISTICS AND RISKS

Having obtained the necessary permissions, we then carried out an audit and risk assessment to cover all aspects of the project., this took into account all third party involvement and interfaces with operatives and the general public The areas of interest include:

Loading Procedures at Aberthaw
Equipment utilised
Transit of Material
Unloading and Operations at Celtic Manor

By this stage, a suitable haulier and earthworks contractor had been identified taking into account a number of factors including, experience with PFA, Scale of Company, Commercial Stability, Health & Safety Record.

Working with the nominated contractors RWE npower then embarked upon an assessment of the practical elements of the project to ensure that the activities posed no threat to Health & Safety and caused the minimum of disruption to people living in the area of activities. Taking each of the three areas above in turn

ABERTHAW POWER STATION

The activities at this site involved the loading and transporting off-site of up to 2,000te/day of PFA. In order to maintain an area of control, it was deemed appropriate to create a dedicated working stockpile area. An area capable of holding a stockpile of approximately 10,000te was bunded off using slipform concrete bunding. This would form a discrete working area and, as the Power Station is directly adjacent to a public walkway on the seafront would act as a visual and acoustic barrier whilst providing a level of protection against any dust nuisance. PFA was loaded directly from conditioning plant and loaded into this area in preparation for transportation to site. During times of reduced generation, which were anticipated due to activities associated with retro fitting of Flue Gas Desulphurisation plant, PFA was taken from on site existing stockpile. To ease traffic congestion in the area, PFA was transported overnight and at weekends, when load out activities had ceased.

All operatives associated with on-site activities were given a formal site induction, informing them of general and specific site rules and conditions. A register of vehicles and staff was maintained with no site access given to staff without the requisite training and certification.

In order to facilitate ease of safe loading and to provide an elevated vantage point for loader driver, a ramp was constructed from PFA.

A traffic management system was put in place which provided a holding area to allow vehicles to wait in safety but in sight of loading area when multiple vehicles were on site. A one way traffic routing system was utilised to reduce the risk of accidents with other site vehicles. Vehicle drivers were issued a route map at site induction, indicating the route through the site, to the loading area and away from the area without cutting across other site traffic.

All vehicles were weighed into the site to provide a tare weight and weighed at the gatehouse upon leaving so that an accurate account of material could be maintained. All vehicles associated with this particular project were identified by means of a permit displayed in windscreen of vehicle.

An example of one of our risk assessments is shown in Figure 1.

Figure 1

RISK ASSESSMENT DOCUMENT		Contractor (UK) Services Ltd	
SITE: Aberthaw Power Station		RISK ASSESSMENT NO.	HTS/CS/ANO/203
NAME: A. N. Other	DATE: 13.09.07	POSITION:	Group Health & Safety Manager

JOB TASK UNDER ASSESSMENT:

Loading and Collection of Ash Product by HGV Tipper

NO OTHER TASK OF WORK OTHER THAN STATED ABOVE TO BE UNDERTAKEN

PLANT EQUIPMENT NUMBER

HGV – Articulated Tipper

EQUIPMENT INVOLVED WITH TASK:

HGV
High Visibility Jacket or Vest/Hard Hat/Safety Boots/Gloves
Safety Glasses or Goggles (in windy/dusty conditions)

SAFETY SYSTEMS TO BE EMPLOYED:

SAFETY DOCUMENT	N	FLOOR OPENING	N
HOT WORK ASSESSMENT	N	SELECTED PERSONS	N
SPECIAL P.P.E.	Y	COSHH	Y
SAFETY HARNESS	N	OTHER	N
GAS TEST	N		

ANY OTHER ASPECTS TO BE CONSIDERED

Observe Safety Rules of Site

RISK ASSESSMENT GUIDE TABLE

HAZARD PROBABILITY	FACTOR	HAZARD SEVERITY	FACTOR
VERY UNLIKELY	1	INSIGNIFICANT	1
REMOTE	2	MINOR – LIGHT DAMAGE	2
FAIR CHANCE	3	MODERATE – DAMAGE / INJURY	3
VERY LIKELY	4	SERIOUS DAMAGE / INJURY	4
ALMOST CERTAIN	5	DANGEROUS - FATAL	5

RISK FACTOR CALCULATION

RISK FACTOR = PROBABILITY FACTOR X SEVERITY FACTOR

RISK FACTOR	CATEGORY	ACTION
1 - 5	ACCEPTABLE	ROUTINE ACTION
6 - 10	ACCEPTABLE	EMPLOY SAFETY SYSTEMS
11 - 15	MARGINAL	REDUCE RISK / EMPLOY ALL SAFETY SYSTEMS
16 - 20	UNDESIRABLE	MAXIMUM CAUTION / CLOSE SUPERVISION
21 - 25	UNACCEPTABLE	MUST NOT BE ALLOWED

RISK ASSESSMENT					See Above for Guide Table & Factor Calculation			
		UNCONTROLLED				CONTROLLED		
NO	HAZARDS	PROB FACTOR	SEV FACTOR	RISK	ACTION TAKEN TO REDUCE RISKS	PROB FACTOR	SEV FACTOR	RISK
1	Collision with vehicles	5	5	25	Site speed limit 15mph on site;	1	5	5
					to be alert for vehicles on site			
					road and operational area and			
					observe speed limit; road to			
					limited to ash loading vehicles			
					one way system in operation;			
					Flashing beacons or hazards to			
					operating on site; site induction			
2	Collision with pedestrians	5	5	25	Pedestrian movements	1	5	5
					authorised persons on site;			
					limited personnel on road to			
					no pedestrians in loading or			
					movement areas;			
					sheeting/unsheeting to be			
					in designated area away from			
					movements;			
					hi-visibility clothing must be			
					times, as well as other PPE, to			
					pedestrians seen at all times;			
					DRIVERS MUST STOP			
					IMMEDIATELY IF THEY LOSE			
					OF PEDESTRIANS DURING			
					MANOEUVRES;			
					Flashing beacons or hazards to			
					operating on site			
3	Collision with buildings	5	5	25	Location of buildings	1	5	5
					prevents likelihood of collision			
					with property			
4	Collision with overhead	5	5	25	No overhead structures e.g.	1	5	5
					cables in loading location; in			
					the event that the location			
					no operations must take place			
					overhead power lines			
5	Slips and Trips	3	4	12	Drivers and operators wearing	1	4	4
					boots; loading and sheeting			
					and concrete; always be alert			
					potential tripping hazards;			
					ensure use all handles and			
					ascending/descending			

6	Falls from Height	5	5	25	Drivers not permitted to climb	1	5	5
					or into trailer; any problems			
					vehicle or sheeting to be			
					site and transport manager;			
					use ladders and 3 point hold for			
					access to gantry			
7	Reversing collisions	5	5	25	No reversing anticipated; any	1	5	5
					reversing operations to be			
					and managed by loading			
					operator to prevent collisions;			
					beacons flashing on vehicle or			
					and reversing alarms operable			
8	Tipover	2	5	10	Loading area level and solid on	1	5	5
					road; slipping agents used to			
					safe discharge of product from			
					vehicle to be loaded evenly;			
					ensure level load by monitoring			
					checking level from gantry			
9	Adverse weather conditions	3	4	12	Extra care to be taken in windy	1	4	4
					conditions; safety of operation			
					Reassessed			

POPULATION AFFECTED / GROUPS ESPECIALLY AT RISK

HGV Drivers/ Plant Operators/Site Personnel

METHOD STATEMENT REQUIRED   YES   REF. NO.

(IF USING WORK INSTRUCTION OFF CHECK LIST STATE REF. NO.)

I have read and I am fully conversant with all the information contained within this document.

Signed………………………………………………………….. (A N Other) DATE ……………………………

Signed………………………………………………………….. (Manager) DATE ……………………………

SUGGESTED FREQUENCY OF REVIEW 2 years

As can be seen from above, the document sets out the work to be carried out, equipment to be deployed and who is responsible for Health & Safety. A list of hazards associated with the activities is then generated. The hazard probability and hazard severity factors associated with all identified hazards are then assessed on a scale of 1-5. The factors are each given a definition of likelihood and consequence. By multiplying the probability by the likelihood, we arrive at an empirical value for the risk (risk factor). Each range of risk factor is then given a rating of acceptability and depending on which scale the risk falls into, a guide of action to be taken is given.

First run of the assessment of risks is taken under uncontrolled conditions, i.e. with no actions taken to control risks. Having identified the risk factor using the above method, the recommended actions are then identified and implemented within the risk assessment document. The same procedure of risk assessment is then carried out under controlled conditions. The resultant risk factor can then be assessed as to its acceptability under site conditions, plus the impact of actions taken to control the risks can be measured.

Another output of the risk assessment is the requirement for a Method Statement, in the above example, it was identified as a requirement, an example of which is shown in Figure 2.

Figure 2.

METHOD STATEMENT

SAFE LOADING OF ASH PRODUCT
BY LOADING SHOVEL
AT ABERTHAW POWER STATION

GENERAL

The operation involves the loading of ash by loading shovel into bulk tipper vehicles for onward road transportation.

SITE SAFETY RULES

All operators shall have received an internal induction with the power station before commencing work and only trained operators will be permitted to operate the equipment.

SITE LOCATION

The operating site is the ash loading area at Aberthaw Power Station, Wales.

THE EQUIPMENT

-
- Front Loading Shovel
- Front Loading Shovel Operator
- HGV tippers
- HGV drivers

PERSONAL PROTECTIVE EQUIPMENT (PPE)

All operators/drivers must wear the following PPE when working on the site:-

- hard hat
- hi-visibility clothing (jacket or vest)
- safety boots
- safety gloves
- safety glasses/goggles

The PPE must be in good working order and the hi-visibility clothing must be bright.

THE METHOD

ACEESS TO SITE AND LOADING AREA

Access to the site is through the Gatehouse where the operator must sign in and out. The operator will then drive his car to the operating area – obeying site road speed limits and traffic signals.

The site speed limit is 30mph and 15mph dependant as directed by relevant signage and must be followed at all times.

Care must be taken when travelling on all road and drivers must be alert for other road users and pedestrians on site.

OPERATING AREA

The ash loading area is a flat concrete/hard standing surface.

The area is not easily accessible by other vehicles or pedestrians other than by HGVs, other large plant and operators/HGV drivers – although the operators must at all times be alert and vigilant for vehicles and persons on foot in the operating area.

LOADING OF VEHICLES

The HGVs will be directed to the ash loading area by the Gatehouse. A one-way system is in operation. The vehicles will not arrive at the loading area until they are unsheeted and ready to be loaded.

The shovel operator will direct the HGV into position, ensuring that the unit and trailer are straight and the vehicle is stationary and will obtain a signal from the HGV driver confirming that he is ready to accept the load. The shovel driver shall ensure that there is sufficient operating area for his vehicle.

The shovel driver will then check his operating area and, ensuring that it is safe from other vehicles and personnel, he will then drive the bucket into the ash heap. On collecting a load the driver will check behind him before reversing backwards and positioning himself ready to load. The operator will then drive the vehicle forward and as he approaches the side of the trailer will raise the bucket, lifting and crowning it over the trailer. The operator shall then discharge the load.

The operator will then carefully recover the bucket and check behind him before reversing backwards away from the vehicle. The operator will take care to avoid hitting the side of the trailer as he reverses backwards.

The operator shall repeat the process, each time ensuring that he loads the vehicle evenly.

The shovel operator shall maintain communication with the HGV driver to ensure that the tipper is loaded correctly and does not exceed the permitted gross weight of the vehicle.
The HGV driver will signal to the operator when loading is completed and the shovel driver move safely away from the vehicle to permit it to exit the area to sheet in a safe location away from the loading area.

PEDESTRIANS

On occasions HGV drivers may seek to exit their vehicle or other shovel operators may be on foot near to the loading area.

On such occasions it is essential that the person son foot are wearing their full PPE including hi-visibility clothing and that they maintain constant communication with the plant operators.

If at any time the operator loses sight of persons on foot he must STOP and check that the operating area is safe.

Contact Details

A.N.Other
Group Health & Safety Manager
07974 999999

Date: 28th January 2008
Review: 12 months

Risk assessments were generated for each individual area of operation, and where necessary a method statement produced to cover individual elements.

TRANSPORT

A designated route from the Power Station to the host site was determined and agreed with the Highways Agency (HA). Whilst not the most direct, shortest or quickest route, it was designated as being the journey that utilised main trunk roads and motorways thereby avoiding areas of local population and villages along the way. This designated route formed part of the induction documentation issued to all drivers. Non adherence to this route would result in immediate removal of the driver from the project.

In the main, articulated, 30te payload vehicles were utilised for the transportation of PFA. This was due in main because of the economic advantage over rigid bodied, 20te payload vehicles. And the associated increase in delivered tonnages/vehicle movement, thereby reducing the actual number of vehicles on the roads.

An advantage that rigid bodied vehicles have over artics is that they are far more stable when discharging their loads. The tipping portion of the vehicle is rigidly coupled to the cabin and motor unit, thereby giving the whole vehicle far more stability overall. Also the length of the vehicle is considerably less, so that when in the tipping position the overall height is consequently less, thereby less at risk of tipping over sideways.

When using articulated vehicles, the requirement for a stable, level and flat tipping area is paramount. It was therefore decided to create a dedicated tipping area for the Artics to discharge. As the vehicles came to site, they came to the designated area, discharged and left the site in a one way ‘roundabout’ route. This maintained the flow of traffic and avoided vehicles crossing each other en route.

In order to further prevent the risk of vehicles tipping over, on board inclinometers and vehicle cameras are utilised. This gives advance warning of the likelihood of instability and gives advance indication of unevenly loaded or material discharging unevenly from the wagon body due to material sticking to the vehicle body, thereby causing possible instability

To ensure safe discharge of the articulated wagons, a clearly defined unloading point was established. On arrival the PFA was tipped and moved by a bulldozer a short distance to a working stockpile. The PFA was then loaded from the stockpile into dedicated site tipping trucks for transportation to the working areas for laying and compaction. The use of the site transport allowed operations to continue in adverse weather conditions.

Compaction was achieved by following the guidelines set out in RWE document Engineering with Ash, Fill. The essence of which is to push the material out in layers not exceeding 225mm, graded to levels with a Grader or Dozer and then compacted either with a towed or self propelled vibrating 12.5 te Roller with 6 – 8 passes.

Handling and compaction of the material was achieved throughout periods of heavy rainfall by following the following guidelines:

Satisfactory compaction can be achieved up to a maximum moisture content of 105% of optimum, should the material become inundated, simply push it to one side until it dries out to an acceptable moisture, the material can then be layered and compacted as before with no adverse effects. The chances of inundation exist primarily when the material is in its uncompacted state. Once compaction is achieved, the low permeability of compacted PFA ($1X10^{-7}$ m/s) means that water does not readily permeate anything other than the very top surface layers. In addition, should the top surface become inundated, simply blade off the top 100mm, push to one side, leave to drain freely and reuse as before.

Once an area was within required height tolerance, a capping layer of 100mm granular material and top soil was applied. This will eventually be dressed and seeded in preparation for the finished working surface.

Throughout the operation the site was regularly visited by staff from RWE npower who ensured that the operation ran smoothly and that any problems were dealt with promptly.

The measures put in place led to the successful placement of the PFA with the minimum of difficulty.

CONCLUSIONS

The supply of PFA to the Celtic Manor site was successful due to the thorough preparation carried out prior to commencement of operations. All major issues, including risk assessments and method statements were addressed at an early stage so that there was no delay to the commencement of operations. The involvement of all relevant parties, including the Environment Agency, the contractor, the client and the power station staff meant that the trust was established and cooperation meant that the operation ran smoothly and that the client and regulators were satisfied with the outcome.

The following points are also worthy of note:

- The actions described were taken under discretionary conditions and with a view to recognising corporate responsibility and mitigating risks
- The project was completed successfully with no reportable incidents,
- Positive PR has been derived from our activities, reported in local and trade press plus national TV coverage
- Future applications of a similar type have been secured

References

Environmental Code of Practice – Stabilising mine workings with pfa grouts" (BRE, 2006)

Waste Framework Directive (75/442/EEC,superseded by 2008/98EC)

Groundwater Directive (80/68/EEC superseded by 2006/118/EC).

http://www.environment-agency.gov.uk

http://www.**celtic-manor**.com