

# Northwich - grouting using 1,000,000 tonnes of conditioned PFA from Drax Power Station

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## **Abstract**

This paper reports on the use of Pulverised Fuel Ash (PFA) in the infilling of former salt mines in Northwich, Cheshire in the UK.

PFA has been used for a number of years within the UK for filling old mine workings. The former salt mines located beneath the town of Northwich in Cheshire had long been identified a major problem in terms of risk of subsidence. As a result, a comprehensive government backed study was initiated to identify the full scale of the problem and consider a way forward. In view of the large volumes involved, the use of either natural virgin aggregates or traditional concrete mixes would have been inordinately expensive. It was therefore decided to utilise a PFA/cement grout based upon extensive experience of successful use of this technique over several years for a number of large-scale mine infill projects mainly in the West Midlands area of the UK.

The project commenced during early 2005 with PFA being supplied from Drax Power Station. The material is supplied in conditioned form with an average moisture content of around 12%. PFA is transported to Northwich by rail with each train carrying some 1,100 tonnes of material. On average around ten trains per week are utilised with total PFA usage being estimated at 1,100,000 tonnes for the project which is expected to be completed during Summer 2007.

## **Introduction**

The salt mines at Northwich in Cheshire date back to the 19th century when four mines, known as Barons Quay, Witton Bank, Penny's Lane and Neumanns, were created resulting from the extraction of salt from a layer approximately 90 metres below ground level. The salt was mined by hand and 8 metre square pillars were left to support the roof. When the mines closed it was realised that water seepage into the mines could dissolve the pillars and so in 1920 the mines were flooded with brine. This has served, to some extent, to protect the pillars and to provide hydrostatic support. In modern salt mines about 25% of the salt is left to provide continuing support for the mine roof. In the four abandoned mines, however, only about 7% of the salt was left.

In recent years it has been established that the pillars in the Northwich mines are too small to provide indefinite support. With the passage of time they were becoming progressively weaker with studies showing that they were unlikely to last another 120 years. This is the period of "comfort" required by investors when considering new developments. Although the pillars are not likely to collapse suddenly, and further settlement will take place gradually, the situation with the abandoned mines effectively blights the development of over 20 hectares of land around the northern part of Northwich town centre.

This paper describes the method that was adopted to infill the mines thereby avoiding any future risk of subsidence.

## **Methodology**

Having established the risk of subsidence arising from the presence of the four salt mines, a comprehensive government backed study was initiated to identify the full scale of the problem and consider a way forward. In view of the large volumes involved, the use of either natural virgin aggregates or traditional concrete mixes would have been inordinately expensive. It was therefore decided to utilise a PFA/cement grout based upon extensive experience of successful use of this technique over several years for a number of large-scale mine infill projects mainly in the West Midlands area of the UK.

A number of alternative fill materials for the mine infilling were considered during the initial study. These included lime waste, colliery spoil and other mine waste, and ground glass cullet. It was concluded that all were less suitable than PFA for various reasons including hazardous nature, handling difficulties, consistency, availability and cost.

PFA has been in large-scale grouting operations for several years because of the technical, rheological, durability and economic advantages it offers.

The advantages of using PFA grouts are summarised below:

- 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.

The volume to be filled at Northwich is large at almost 800,000 cubic metres. An equivalent amount of brine, equivalent to 176,000,000 gallons, needs to be removed from the mines and taken elsewhere. The PFA/cement grout comprises approximately 95% PFA mixed with approximately 5% cement. Whereas PFA/cement grouts are normally mixed with water prior to being pumped underground, at Northwich use is being made of some of the extracted brine in place of water as there is a risk that water could “bleed” from the grout in the mine and dissolve part of the salt pillars.

With the PFA, cement and brine having been mixed at the surface, the grout is injected into the mines through boreholes and, as this happens, the brine is displaced and removed by pumping. The displaced brine is delivered by rail to the British Salt works at Middlewich for use in their production process.

### **Material Transport**

The main work site for the Northwich scheme has been established adjacent to a railway siding in an area known as Winnington. This site was selected because of its ready access to rail transport. This meant that the main fill material, PFA, could be delivered to the site by train rather than by road. Given that up to 2,200 tonnes of PFA is delivered to the Winnington site each day during the two and a half year duration of the project, the use of road transport would have required around 180 lorry movements a day between Drax Power Station and Northwich (90 each way). This amount of lorry movements was considered to be unacceptable, particularly through Northwich itself.

Having regard to the cement used in the scheme this is required in much smaller quantities and, as such, road transport is being used. This involves around three lorries a day each way with these lorries not passing through the town centre of Northwich. A similar quantity of salt is also required and this too is delivered by road. The salt is needed because the conditioned PFA contains moisture which, like the mixing water, could bleed from the grout and cause the salt pillars to dissolve. Salt is added to the grout to turn this moisture into brine that cannot then dissolve more salt.

On arrival at the Winnington site the materials are conveyed to storage bins and silos. The grout is then mixed at the site using mixing equipment similar to that used in the production of ready-mixed concrete.

In order to avoid potential nuisance associated with noise at the Winnington site, loading and unloading of materials at the site (including rail shunting) is restricted to the period between 08.00 hours and 19.30 hours each day.

Grout mixing itself is a 24-hour process. However, whilst wheeled loaders may be used during the day to transfer materials from storage to the mixing plant, only electrically-driven conveyors are used at night to reduce noise.

### **Transport of Conditioned PFA by Rail from Drax Power Station**

Upon being awarded the contract to supply PFA to the Northwich Mine Infill project a dedicated conditioned PFA rail-loading facility was constructed at Drax Power Station. This was designed so as to allow for the loading of two trains per day at the power station, with each train having a capacity of 1,120 tonnes.

Drax Power Station is the largest coal-fired power station in the UK with an output capacity of 4,000 megawatts from its six generating units. Drax currently provides enough power to meet 7% of the UK's electricity needs. Drax produces around 1,000,000 tonnes of PFA each year together with around 220,000 tonnes of FBA. In a typical year approximately 85% of Drax's PFA production will be sold. All FBA is currently sold.

PFA which is not sold at Drax is sent to either disposal or temporary stockpile to a site within the power station boundary known as Barlow. The PFA is transported to Barlow in conditioned form by conveyor. Two 1050mm width troughed conveyors run from the power station to Barlow with the conveying system running at a speed of 3.05 metres per second. The conveyors are fed with conditioned PFA from three continuous product mixers each operating to a maximum of 250 tonnes per hour. The installed plant therefore has a capacity to deliver up to 750 tonnes of conditioned PFA per hour to the Barlow site.

The conveyor system at Drax runs parallel to a rail track and, in planning for the construction of a conditioned PFA rail-loading facility, a suitable site was identified adjacent to the rail track and also in close proximity to a junction house within the conveyor system.

The basic design of the rail-loading facility at Drax is as follows:

- A new conveyor has been installed that runs from the junction house on the existing conveyor system at high level across a site access road.
- A concrete pad (20 metres by 60 metres in size) has been laid directly adjacent to the rail track onto which conditioned PFA is deposited from the new conveyor. The concrete pad has the capacity to hold approximately 2,500 tonnes of conditioned PFA. The pad has a retaining wall to one side which has been created to both shelter the material from any prevailing wind conditions and also to aid in the loading process. As well as having the capacity to store up to 2,500 tonnes of conditioned PFA, the concrete pad has been designed so as to allow movement of mobile plant to allow loading of trains to take place from the pad. This plant comprises high level loading shovels which are utilised to pick up the stored PFA and load it into box wagons on the adjacent rail track.

The concrete pad is covered by a network of dust suppression pipework and sprays that ensure that any potential dust nuisance is controlled, with deposit gauges strategically located to monitor the operation. In addition to this a spray bar has been constructed over the rail line from which water and/or polymer can be sprayed onto the surface of the PFA within the rail wagons to ensure that no dust nuisance arises during the transportation of the material to Northwich.

- The loading plant provided allows for the loading of 16 MBA type box rail wagons of around 70 tonnes capacity each. This results in each train carrying a total material weight of 1,120 tonnes. The scheme was originally designed so as to consistently meet a loading time target of 3 hours for each train. In practice, trains are typically loaded in around 2 hours.
- The loading shovels are fitted with weigh cells with the aim being to achieve accuracy within the loading system of  $\pm 1\%$ . In this way each train is loaded with the optimum amount of conditioned PFA.

During those times when there is insufficient “fresh” conditioned PFA available to maintain stock levels on the concrete pad, stockpiled material is recovered by dump truck from the Barlow site itself.

As well as designing a rail-loading facility capable of loading two trains per day within specified time periods, it was also necessary to plan the times at which the trains could enter and leave the Drax Power Station site in view of the high volume of other rail traffic within the site associated with movement of coal, limestone and gypsum. In addition to this, it was necessary to ensure that the loaded trains would arrive at the Winnington site in Northwich within the specified times of 08.00 hours and 19.30 hours. Following lengthy discussion with the rail operating company, EWS Railways, and Network Rail, who manage the rail system itself, the following programme was eventually agreed:

The first train arrives at Drax at 16.00 hours and leaves the power station at around 19.00 hours. The second train (during those periods when two trains per day are required) arrives at Drax at 02.00 hours and leaves the power station at around 05.00 hours. The time slots are designed to allow for trains to be held at a site known as Healey Mills en route to Northwich such that, in the event of any delays, deliveries to the Northwich site can still be made on time.

On arrival at the Winnington site, conditioned PFA is removed from the MBA rail wagons by a clam-shell grab and loaded onto a conveyor system which takes the material into a storage shed which has a capacity of around 3,000 tonnes. PFA is then conveyed from the storage shed direct to the grout mixing plant before being pumped via the pipeline system to the injection boreholes.

## **Programme**

The mines are being filled in the following order:

1. Penny's Lane mine.

2. Neumann's mine.
3. Baron's Quay mine.
4. Witton Bank mine.

In technical terms there is no need to fill the Penny's Lane and Neumann's mines. They are much smaller than the other two mines and investigations have shown that they are long-term stable. It was decided, however, that it would be necessary at the start of the project to carry out some trial filling to ensure that the proportions of the grout mix, the rate of filling, the rate of brine extraction and other details were correct. This period of filling the two smaller mines allowed for fine-tuning of the method. It was also clear that the costs of filling the two smaller mines would be marginal in terms of the overall scale of the project.

The mixed grout is pumped to a distribution centre in the mines area by means of a temporary pipeline. Grout injection boreholes are drilled throughout the mine areas in a pattern designed to intercept the mine workings on a 30-metre grid spacing. At the ground surface the drilling rigs have to be set up where access permits and, in view of this, it is necessary for some of the holes to be drilled at an angle so as to enter the mine at the correct place. In adopting this method there will be no need for buildings or other structures to be demolished to allow drilling to take place.

Four pipelines – two for grout and two for brine – have been channelled from the mixing plant at Winnington and travel under the River Weaver into Northwich, about one and half miles away.

As part of the work, 500 vertical and inclined boreholes are being drilled into the mines to enable the grout to be pumped inside. If laid end to end these boreholes would cover a distance of around 48 kilometres.

Work is taking place progressively across the mine areas from west to east. Up to six drilling rigs are used at any one time. It commonly takes between one to three days to drill each hole, before the drilling rig moves on, and then several weeks to inject grout at each position.

As grout is injected into the mines, brine is displaced and needs to be removed. From each brine extraction borehole brine is pumped to a storage lagoon before being pumped along the main pipe route back to the Winnington site for transfer to rail tankers and transport to the British Salt works.

The mixing of the PFA/cement grout, and its pumping into the pipeline system and injection boreholes, needs to be carried out as continuously as possible. This is because each time the flow of grout stops for more than a few minutes, the pipes need to be flushed out to prevent the grout from blocking them. The grout mixing and injection is therefore a 24-hour, 7-day process other than for essential maintenance periods. This also helps to minimise the overall programme of works.

Filling of the mines with the PFA/cement grout began in January 2005, with completion of the project forecast to take place during Summer 2007. The mines will then be strictly monitored for a further 10 years.

The stabilisation of the mines will allow work to begin on the town's £200 million regeneration plan known as the "Northwich Vision".

As part of this plan the size of the town centre will be doubled to include a Cultural Centre, new retail development and vibrant waterfront area to attract tourists.

## **CONCLUSIONS**

The former salt mines located beneath the town of Northwich in Cheshire had long been identified a major problem in terms of risk of subsidence. Following comprehensive studies a scheme for infilling the mines was devised involving the use of a PFA/cement grout. This technique has been used successfully in UK over several years for a number of large-scale mine infill projects.

The project commenced during early 2005 with PFA being supplied from Drax Power Station using dedicated rail wagons at a rate of around 11,000 tonnes per week. The project, which should be completed during Summer 2007, will result in the possibility of being able to develop over 20 hectares of land around the northern part of Northwich town centre that had previously been blighted.

## **References:**

W S Atkins Consultants Limited "Northwich Salt Mines Stabilisation, Planning Application, Technical Summary". May 2001.