UNITED KINGDOM QUALITY ASH ASSOCIATION

CASE STUDY

Northwich Mine Infill Project

Introduction

The salt mines at Northwich in Cheshire date back to the 19th century when four mines, Barons Quay, Witton Bank, Penny's Lane and Neumanns, were created resulting from the extraction of salt from a layer between 80 and 90 metres below ground level. There are two layers of salt beneath the town, but the lower layer being of superior quality, was the one extensively mined. The salt was mined by hand and 8 metre square pillars were left to support the roof. 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. It was realised that the remaining pillars were insufficient and remedial works were required to remove the blight of future potential settlement or even collapse from Northwich town.

Methodology

A comprehensive study carried out by Vale Royal Borough Council and managed by English Partnerships on behalf of the Governments' Land Stabilisation Programme 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. Though a number of materials were considered, it was decided to utilise 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. This was the first flooded salt mine to be filled in the UK and the largest single PFA grouting contract.

Figure 1 - The stocking area at Drax Power Station

The volume to be filled at Northwich was large at about 750,000 cubic metres. An equivalent amount of brine, 800,000,000 litres, needed to be removed from the mines and taken elsewhere. The PFA/cement grout comprised approximately 96% PFA mixed with approximately ~4% cement. PFA/cement grouts are normally made with fresh water, but at Northwich use was made of some of the extracted brine in place of water. This was done to prevent any risk that fresh water could dilute the brine in the mine and subsequently dissolve the remaining salt pillars.

With the PFA, cement, salt and brine were mixed at the surface, the grout was injected into the mines through boreholes and, as this happens, the displaced brine was removed by pumping. Some excess displaced brine not used in the grout manufacturing process was delivered by rail to the British Salt works at Middlewich for use in their production process.

Material Transport

Transport of Conditioned PFA by Rail from Drax Power Station

A dedicated conditioned PFA rail-loading facility was constructed at Drax Power Station for the contract, see Figure 1. 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 1,260 tonnes. The freshly conditioned ash was supplied at 11 to 14% moisture content.

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 provides enough power to meet ~7% of the UK's electricity needs. It 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 and all its FBA production are sold. The Drax PFA had a loss on ignition between 5 to 7% and a fineness of ~25% passing a 45µm sieve.

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

- A new conveyor plus a concrete storage area were built. This has the capacity to hold approximately 2,500 tonnes of conditioned PFA. The concrete storage area was also designed so as to allow movement of mobile plant enabling the loading of trains to take place. This plant comprises high level loading shovels to pick up the stored PFA and load it into box wagons on the adjacent rail track.

- The storage area was covered by a network of dust suppression sprays that ensure that any potential dust nuisance was controlled, with deposit gauges strategically located to monitor the operation. In addition to this a spray bar was constructed over the rail line from which water and/or polymer could be sprayed onto the surface of the PFA within the rail wagons to ensure that no dust nuisance arose during the transportation of the material to Northwich.

- The loading plant provided allowed for the loading of 18 MBA type box rail wagons of around 70 tonnes capacity each. This resulted in each train carrying a total material weight of 1,260 tonnes. The scheme was originally designed so as to consistently meet a loading time target of 3 hours for each train. In practice, trains were typically loaded in around 2½ hours.

- The loading shovels were fitted with weigh cells with the aim being to achieve accuracy within the loading system of ±1%. In this way each train was loaded with the optimum amount of conditioned PFA.

During those times when there was insufficient "fresh" conditioned PFA available to maintain stock levels in the storage area, stockpiled material was recovered by dump truck from the Barlow site itself.

Unloading the ash at Northwich

The main site for the Northwich scheme was established adjacent to a railway siding in Winnington in the Brunner Mond factory complex. This site was selected because of its ready access to rail transport as up to 2,520 tonnes of PFA were required daily. Road transport would have put a great deal of strain on local roads, although cement was delivered by road tanker as only ~3 loads per day were required. A similar quantity of salt was also required and this too was delivered by road. The salt was added to the grout because the conditioned PFA contains moisture that could dilute the brine.

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

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

Grout batching and mixing itself could have been operated on a 24-hour basis, though an 18 hour double shifting system was found to be satisfactory. However, whilst wheeled loaders were used during the day to transfer materials from storage to the mixing plant, only electrically-driven conveyors were used at night to reduce noise.

As there were restrictions to delivery times, a timetable was agreed with EWS Railways, and Network Rail. On arrival at the Winnington site the train was split into two sections of 9 wagons and the conditioned PFA was removed from the MBA rail wagons by a clam-shell grab, see Figure 2, and loaded onto a conveyor system, see Figure 3, which screened the material and took it into a storage shed which had a capacity of around 3,000 tonnes, see Figure 4. PFA was then conveyed from the storage shed direct to the computer controlled, see Figure 5, grout mixing plant, see Figure 6. This was fed by loading shovel as seen in Figure 8.

Programme

The mines were filled in the following order:

1. Neumann's Mine.
2. Penny's Lane Mine.
3. Baron's Quay Mine
4. Witton Bank Mine.

The mixed grout was pumped using two Gheo pumps, see Figure 7, to a distribution centre in the mines area by means of a temporary pipeline. These pumps were capable of pumping up to 100m^3 per hour. The pipeline was up to 3km in length and the grout had to be as stiff as possible while still being pumpable. Two Schwing pumps were available on standby in case of failure of the main Gheo pumps. Grout injection boreholes were drilled throughout the mine areas in a pattern designed to intercept the mine workings on 30-metre grid spacing. Four pipelines - two for grout and two for brine - were channelled from the mixing plant at Winnington and travelled under the River Weaver into Northwich, about 2km away. At the ground surface it was 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 was no need for buildings or other structures to be demolished to allow drilling to take place. As part of the work, 200 vertical and inclined boreholes were 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 17km assuming an average borehole depth of 85m.

Figure 3 - Ash handling at Northwich

As the mines are some 80 to 90m below ground level, grouting pressures were up to 6 bar (90 psi) at the point of injection and 14 to 15 bar (~220 psi) in the mine when the hydrostatic pressure was included. These high pressures resulted in problems in extracting cores from the hardened grout due to the expansion of entrapped air disrupting the cores taken. As a result the samples were taken at later ages than originally programmed when sufficient strength had been gained to resist the bursting forces.

Figure 4 - Ash storage at Northwich

Figure 5 - Computer controlled batching

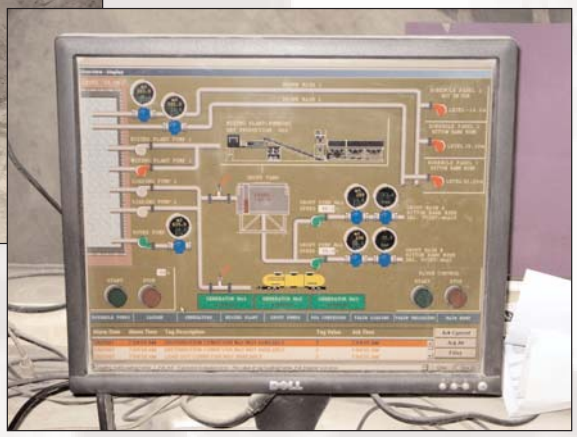

Figure 6 - The grout mixing plant hoppers

Figure 7 - The two Gheo grout pumps

Work took place progressively across the mine areas from west to east. Up to six drilling rigs were used at any one time. It commonly took between one to three days to drill each hole, before the drilling rig moved on, and then several weeks to inject grout at each position. As grout was injected into the mines, brine was displaced and removed.

The mixing of the PFA/cement grout, and its pumping into the pipeline system and injection boreholes, needed to be carried out with as much continuity as possible. This was because each time the flow of grout stopped for more than a few minutes, the pipes needed to be flushed out to prevent the grout from blocking them. Filling of the mines with the PFA/cement grout began in January 2005 and the project completed mid-2007 with a 12 month monitoring period following on.

Figure 8 - A loading shovel was used to feed the batching plant

The stabilisation of the mines allows 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.

Conclusion

The former salt mines located beneath the town of Northwich in Cheshire had long been identified as 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 was consistently ahead of schedule and under budget. As a tribute to the implementation of the project many members of the public were not aware that this work was going on, often very close to the town centre.

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 resulted in the possibility of being able to develop over 32 hectares of land around the northern part of Northwich town centre that had previously been blighted.

Acknowledgments

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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.