Unspoiling the environment

Sustainable quarry restoration using colliery spoil extractive waste

By Paul Hubbard, MJCA

Fig. 1. Aerial photograph (taken in 2009) of Whitwell Quarry and the Belph and Whitwell colliery spoil tips

Finding suitable restoration materials for quarries where overburden is in scarce supply can be difficult and costly. Even restoration using inert waste materials where placed in sensitive groundwater environments under the provisions of the Landfill Directive can result in the need for long-term management care, and potential liabilities.

A novel solution to restoration was established at Lafarge Aggregates Ltd's Whitwell Quarry, in Derbyshire, which sought to both aid the restoration of the quarry and improve the local environment through the use of extractive waste materials comprising colliery spoil. There is a range of technical and operational challenges associated with the use of such extractive waste material, and a series of studies was carried out by MJCA to assess the suitability of these materials for their intended use through detailed hydrogeological assessment of the risks to controlled waters and to address the relevant engineering, regulatory and permitting requirements.

To the east of Whitwell Quarry lie two large colliery spoil tips from former coal workings in the area which date back to 1894 (fig. 1.). The colliery spoil tips lie open to weathering processes and there is evidence to suggest that, without ongoing long-term management, water draining from the spoil tips has an impact on the quality of the nearby watercourses and underlying groundwater. The tips overlie a part of the dolomitic limestone and prevent access to this valuable mineral reserve. The solution sought was to relocate the spoil from one of the tips, named 'Belph Tip'. This approach would not only allow Lafarge to gain access to the limestone reserves to the east of the main quarry, but would also provide materials that could be used in the restoration of the main quarry and remove one of the spoil tips which currently is affecting the local environment.

At the quarry Lafarge excavate the dolomitic limestone from two benches to provide material for a kiln located at the site, which produces high-grade refractory products, and from a lower, third bench for aggregate products. The limestone is a principal aquifer supporting a number of groundwater abstractions in the wider area. Whitwell Quarry is also located close to Cresswell Crags, which is a Site of Special Scientific Interest (SSSI) and a Scheduled Ancient Monument (SAM). Cresswell Crags comprises a number of prehistoric limestone caves, containing important Palaeolithic deposits, and a limestone gorge in which the Crags Pond is formed by the Millwood Brook.

Colliery spoil is classified as an extractive waste and is exempt from regulation under the Landfill Directive and the waste-management permitting regulations (WMPR), which were in place at the time of application for the relocation of colliery spoil to the quarry. The assessment of risks to groundwater from processes not covered by the provisions in the WMPR, which may lead to the indirect discharge of hazardous and non-hazardous substances, is subject to the 1998 Groundwater Regulations (since revoked and replaced) and through the need to ➤

obtain a 'Groundwater Authorisation' at the time of the application. To facilitate the relocation of the colliery spoil to Whitwell Quarry, a Groundwater Authorisation was granted by the Environment Agency in 2008, based on the conclusions of the quantitative hydrogeological risk assessment and engineering assessments together with other necessary application documents completed by MJCA in 2007.

Fig. 2. Mixing of kiln dust and colliery spoil prior to compaction to form the base of the perimeter side wall

Basis of the hydrogeological risk assessment

In its current location the colliery spoil at the surface of Belph Tip is exposed to erosion and weathering processes. In the presence of air, iron sulphide minerals that are present in the spoil start to oxidize to iron sulphate and iron hydroxides catalysed by microbial processes, which, in the presence of water, results in the production of mild sulphuric acid. These acidic conditions increase the solubility and mobility of elements present in the colliery spoil, including metals. The acidity of the resulting aqueous solution and the oxidation conditions affect the rate at which metals are leached from the spoil tip. Monitoring data for the surface-water runoff from the tip area, which currently is collected and managed, show measurable concentrations of sulphate and certain metals, confirming that these processes occur at the site.

The underlying principle of the management of the relocated colliery spoil is to minimize the development of the acidic pore water through minimizing the supply of oxygen and water. Following placement the colliery spoil is compacted inside an engineered perimeter layer to reduce the void space, thereby lowering the permeability, reducing the availability of oxygen and creating a more anaerobic environment. Limiting the presence of oxygen will, in turn, minimize the generation of sulphuric acid and the leaching potential of contaminants in the spoil.

Compacted spoil will be sealed by a low-permeability capping layer. The capping layer will minimize the volume of water passing into the spoil, and thereby the amount of dissolved oxygen that, potentially, could generate acidic conditions in the uppermost spoil layer. A small amount of oxygen, in the form of dissolved oxygen in water, is expected to infiltrate through the cap even though it is engineered to a low permeability. Acidic pore water migrating slowly from this upper layer through the underlying compacted colliery spoil will be neutralized to some degree in the more anaerobic environment through the process of reduction, which is essentially the reverse of the oxidation process. Neutralization processes also take place as a result of the contact of acidic water with the natural mineralogical constituents in the spoil, such as carbonates and, to a lesser extent, silicates that buffer the acidic water. The potential for neutralization of acid can be quantified through acid neutralization capacity (ANC) testing of the materials. As the acidity in the pore water reduces, the solubility of many ions in solution decreases and certain contaminants previously mobilized will precipitate out of solution as hydroxide, carbonate and sulphide compounds.

Furthermore, other processes, such as adsorption and cation exchange, will occur in the more anaerobic lower layer of the spoil, whereby certain ionically charged contaminants, such as metals, will be exchanged on to the surface of the spoil. The hydrogeological risk assessment undertaken by MJCA included running various models based on site-investigation data to demonstrate that the ANC in the anaerobic layers of the colliery spoil alone will be sufficient to neutralize any acidic pore water generated from the upper layer.

The area of the quarry in which the colliery spoil is placed is lined with a 'reactive' perimeter layer comprising a 1m thick layer of the colliery spoil mixed with 5% limestone kiln dust. The limestone kiln dust (also referred to as doloflour) is a by-product of the kiln process at Whitwell Works and was previously has been landfilled at the Whitwell Quarry complex. The proportion of the highly alkaline kiln dust used in the barrier is calculated to ensure that there is sufficient neutralization capacity for the predicted amount of acidic pore water that may be generated from the upper layers. The cap design placed on the perimeter layer also incorporates a proportion of kiln dust to aid the neutralization of acidic rainwater infiltrating to the underlying colliery spoil. The combined effect of various neutralization processes, ANC and cation exchange minimizes the risk of migration of significant quantities of contaminants through the compacted layer of spoil.

Current works

In support of the application for the restoration works, MJCA produced a method statement for the earthworks together with various engineering assessments. A series of stability analyses for the engineered slopes to be placed against the near vertical sides of the quarry were run using slope-stability software, taking into account the placement of the colliery spoil and the potential future rise in water levels at the base of the slope following cessation of quarry dewatering.

The construction of the perimeter layer base and the engineered side slopes commenced at the site in 2010 (as shown in figs 2 & 3). The colliery spoil relocated from the tip is mixed with the kiln dust using a rotavator, placed in 250mm thick layers and then compacted. These works are being overseen by geotechnical engineers from MJCA and verified through laboratory testing of core samples taken from the compacted layers for moisture, density and permeability characteristics, and the use of in-situ nuclear density moisture gauge tests to confirm that

Fig. 3. Rotavator plant mixing a layer of kiln dust and colliery spoil prior to compaction for the formation of the basal perimeter layer

the barrier layer is placed to the approved engineering specifications.

As the quarry is located in a sensitive setting, all aspects of the colliery spoil relocation programme are carefully designed and managed to minimize risks and potential impacts on the environment. On completion of the works, approximately four million cubic metres of colliery spoil will have been relocated into the quarry from Belph Tip as part of the main quarry restoration works.

Legislative changes

There have been a number of relevant legislative changes since the Groundwater Authorisation was obtained for the relocation of the colliery spoil at Whitwell Quarry. The 1998 Groundwater Regulations and the 2007 Environmental Permitting regime have been replaced by The Environmental Permitting Regulations (England and Wales) 2010, which cover the permitting of all water discharge and groundwater activities, including former Groundwater Authorisations.

'Extractive wastes', such as colliery spoil tips, are now regulated under the scope of the Mining Waste Directive (MWD). The MWD was adopted by the European Parliament in May 2006 and is currently implemented in England and Wales through the 2010 Environmental Permitting Regulations. Under the MWD, extractive wastes remain exempt from the Landfill Directive. While there have been a number of changes to the regulations in respect of the use of extractive wastes for quarry restoration, the restrictions on the management of indirect discharges to groundwater from extractive waste for the protection controlled waters remain similar to those previously specified under the 1998 Groundwater Regulations, although new authorizations are issued as an Environmental Permit. Therefore, the strategy applied at Whitwell remains an option worthy of consideration at other restoration projects where extractive waste materials can be sourced readily.

Sustainable aims

By applying an integrated approach at Whitwell Quarry, supported through the detailed technical hydrogeological risk assessments and engineering design carried out by MJCA, the result has been a sustainable and commercially effective solution for quarry restoration management. The removal of the Belph Tip will minimize the potential for ongoing generation of pollutants. The recovery of the locally sourced colliery spoil and kiln dust results in the consumption of fewer natural resources, and the proximity of these materials to the restoration location limits emissions from transportation to the restoration area. These initiatives are in keeping with Lafarge's sustainable development philosophy.

For further information regarding the hydrogeological assessment of risk to controlled waters, geotechnical assessment of quarry developments, or current legislative controls and permits associated with quarry, mining or landfill waste management, contact Paul Hubbard or Leslie Heasman at MJCA on tel: (01827) 717891; or email: mjca@mjca.co.uk

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