Remedial Works at Frongoch Lead and Zinc Mine

Sean Matthew Collier

Graduate Environmental Scientist, AECOM, Environment Liability Solutions
sean.collier@aecom.com

[1]Richard Knott, [2]Paul Edwards

[1]AECOM, [2]Natural Resources Wales

1. Location & Site History

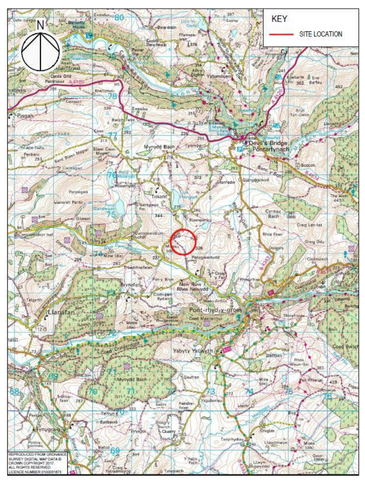

Figure 1. *Frongoch Mine site location.*

The former Frongoch Mine, one of the largest in North Ceredigion, is located near Pontrhydygroes in central Wales and approximately 15km southeast of Aberystwyth.

Mining at Frongoch began in the mid 1700s, with activity significantly increasing through the acquisition from Lisburne Mines in 1834. Mine work excavated lead reserves identified in mineral veins present to the north of the site area. Underground mining culminated in 1910, however salvation in later years reworked mine spoil for the extraction of zinc and lead that had once been deemed uneconomical to recover.

Frongoch Mine is a major source of metals pollution, causing a chemical and ecological impact on downstream water courses; Frongoch Stream, Nant Cell, Nant Cwmnewydion, River Magwr and significantly contributing to WFD zinc failure in the River Ystwyth. The primary pollutants of lead, zinc and cadmium originated at the abandoned Frongoch Mine, and have attributed to failing environmental quality standards by the European Water Framework Directive.

2. Previous Remediation

Natural Resources Wales (NRW) has an ongoing commitment to restore the surrounding water courses and land to their natural state, implementing numerous successful remediation strategies to date. In 2011, the Frongoch Stream was diverted to prevent it flowing directly into the underground workings, thus reducing the contaminated discharge from the Frongoch Adit.

Phase 1 remediation, completed in 2013, focused on the construction of a catchment channel located on the perimeter of the mine, acting to capture surface runoff and divert it away from areas of potential contamination to a lined flood attenuation pond.

During Phase 2 remediation, completed in 2015, waste dumps were re-shaped and capped with a low permeability clay cap to prevent water ingress, and restoration soils to encourage re-vegetation. Further catchment channels and a series of linked ponds were constructed, creating a wetland habitat and to further control surface runoff.

Figure 2. *Frongoch Mine (above) prior to remediation in 2010, and (below) post Phase 2 remediation in 2015 (www.aspectsofwales.co.uk/frongochinfo.htm).*

3. Phase 3 Remediation – AECOM

AECOM was commissioned by NRW to undertake the design and construction of a Phase 3 remediation scheme, involving the placement of a low permeability geosynthetic clay liner over the remaining mine waste not capped during Phase 2, in conjunction with hydroseeding the banks of the flood attenuation pond with an analogous seed mix. The intention is that lead and zinc pollution from erosion and infiltration of the surrounding watercourses should significantly decrease.

The geosynthetic clay liner chosen was BENTOMAT AS4000-1, consisting of a layer of sodium bentonite between a woven and nonwoven geotextile, which are subsequently needle punched together to provide internal reinforcement. The internal reinforcement minimises clay shifting and thus maintains consistent low permeability and performance under a wide variety of field conditions. Each clay liner was attached to the adjacent liner by an overlapping seam, sealed with a H_2O sodium bentonite saline powder.

Prior to deployment of the geosynthetic clay liner, the underlying surface had to be prepared by scouring and proof rolling the ground surface to remove any angular material that may cause potential puncture. Each liner was installed using a suspended I-beam to minimise roll deformation and subsequently covered with a 100mm blinding layer of material, followed by a further 200mm of screened material. The final covering was an organic rich restoration soil to encourage vegetative growth across the site.

Technical Data	
Material Property	**Typical Value**
BENTOMAT AS4000-1	
Index Flux	$6.0x10^{-09}$ $(m^3/m^2)/s$
Hydraulic Conductivity	$3.0x10^{-11}$ m/s
Total Mass/Unit Area	4.33 kg/m^2
Bentonite Mass/Unit Area	4.00 kg/m^2
Tensile Strength	12.0/12.0 kN/m
Puncture Resistance (CBR)	2.0 kN
Thickness	6.5mm
Roll Length	40.0m
Roll Width	5.0m

Technical Data	
Material Property	**Typical Value**
BENTONITE	
Free Swell	25 ml/2g
Fluid Loss	Max 18 ml
Montmorillonite Content	8-%

Technical Data	
Material Property	**Typical Value**
GEOTEXTILES	
Non-Woven Mass/Unit Area	200 g/m^2
Woven Mass/Unit Area	130 g/m^2

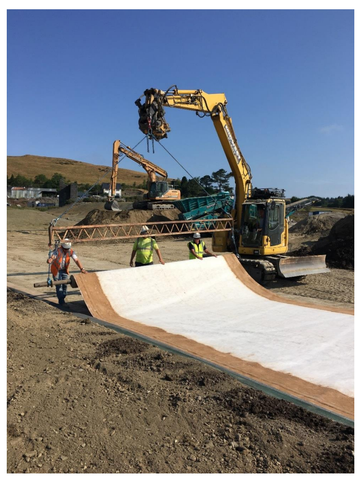

Figure 3. *Deployment of the geosynthetic clay liner using a suspended I-beam and excavator.*

Figure 4. *The full extent of the geosynthetic clay liner once deployed.*

Figure 5. *Covering the geosynthetic clay liner with a minimum 100mm blinding layer of materials to inhibit the potential for puncture or damage by angular material.*

Figure 6. *Fully covering the liner with a minimum of 300mm material before vehicular access. A final 50-100mm restoration soils cover the liner to encourage vegetative growth.*

5. Project Role - Construction Quality Assurance Inspector

As part of the delivery team, Sean was employed in the Construction Quality Assurance role, acting as an employers' agent between NRW and the contractor. Without any formal role in the administration of the works or site engineering, the Construction Quality Assurance Inspector is free to independently monitor compliance and conformance to the specification. Sean's responsibilities of the Construction Quality Assurance Inspector involved:

- A comprehensive understanding of the site health & safety, coupled with the responsibility to stop work if required. Through the duration of the project, Sean developed a relationship with the contractor to ensure safe working practices whilst on site, deeming it necessary to stop work during the third week of the project after complications arose. Seam communicated the appropriate actions and response to the contractor and reported these findings back to NRW.
- Assess all manufacturers' quality control certificates to confirm that the material meets the requirements of the specification prior to installation and appraise the method statements submitted by the contractor detailing the proposed deployment and seaming techniques.
- Inspection of each GCL roll from delivery to deployment for any significant damage or defects that may have occurred through transport, including any imported materials and sources. Sean found complication resulting from handling and delivery, and requested the GCL to be repaired or replaced on three separate occasions to guarantee compliance with the manufacturers specification, and establish that a defect free tie-in with the existing capping was constructed.
- Whilst on site, Sean was able to implement professional support and guidance to the contractor, witnessing all panel deployment and excavation of anchor trenches throughout the installation process. During the Construction Quality Assurance role, Sean refined the method statement provided, aiming to improve the safety and efficiency of the installation process.
- Provide daily comprehensive progress reports to AECOM and NRW to ensure that work progressed according to schedule, including maintaining a fully referenced as-built panel layout plan. Liaising with the contractor ensured excellence and a professional level of care was maintained.

6. Conclusion & Discussion

It is expected that the benefits of Phase 3 remediation will be:

- Completion of the Surface Water Management System eliminating erosion, transport and dissolution of mine spoil. This enables NRW to focus on the treatment of the much reduced volumes of heavy metal polluted groundwater discharges thus enabling downstream waterbodies to achieve Good Ecological Status. Similar remediation may be implemented at similar metal mines causing pressure on recipient water bodies.
- Reduced contaminated sediment being mobilised downstream, decreasing the likelihood of flood risk and environmental impact.
- A large area of mine waste will be re-established in part as a wetland habitat surrounded by acid grassland, significantly increasing the biodiversity across the site.
- The GCL is considered sustainable with minimal maintenance. Dependant on weather, covering and restoration soils may need to be monitored for erosion, and GCL for impairment through wet dry cycling.

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References

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2. Frongoch Mine Remediation, www.aspectsofwales.co.uk/frongochinfo.htm, access 19/07/2018
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