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METROPOLITAN MINE UNDERGROUND EMPLACEMENT OF COAL REJECTS - A CASE STUDY

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ABSTRACT: Metropolitan Collieries Pty Ltd (MCPL), a wholly owned subsidiary of Peabody Energy Australia Pty Ltd, has developed a method to emplace coal mine rejects underground. The rejects are processed to form high density slurry which is pumped into underground workings. The technology will eliminate the transport of rejects by truck through the township of Helensburgh, thereby significantly reducing the environmental impacts of dust, noise, and visual amenity as well as improving road safety. MCPL conducted a range of investigations from initial laboratory studies, field trials and a pilot underground emplacement facility. Key flow characteristics of the high density slurry include a pumping distance of up to 8 km, non-settling; and a drained strength that eliminates the liquefaction risk.

INTRODUCTION

Metropolitan Mine is an underground longwall coal mine located in Helensburgh, midway between Wollongong and Sydney. Mined coal is washed on site to produce a high quality coking coal. The washing process separates the product coal from the waste rock, typically shales and siltstone that comprises 17% of the total mined material. This generates approximately 300 000 tonnes of rejects per annum.

A major environmental challenge for Metropolitan (and the industry more generally) is the disposal of coal rejects. The township of Helensburgh was founded in 1888 to provide housing and support services for the mine and for many years coal mine rejects were used to support town infrastructure such as construction of sporting fields. Later, the rejects were stored on the mine site, but storage space became exhausted in the mid 1990s. Prior to underground emplacement, all rejects were transported by truck to an emplacement facility at a disused washery at Glenlee, near Campbelltown. The only transport route to Glenlee, or any other external site, is through the main street of Helensburgh. This creates environmental issues of noise and dust, together with other issues such as road safety and visual amenity.

Peabody Energy Australia Pty Ltd took ownership of Metropolitan Mine in 2006 and recognised that future development would be limited unless an alternative to trucking rejects through town could be found. An investigation into the emplacement of coal mine rejects into abandoned underground workings by high density slurry was conducted.

This paper describes the laboratory, surface field investigations, and pilot underground plant leading to successful development of the emplacement method and presents the potential future applications of the technology.

METROPOLITAN FILL SPECIFICATIONS

The specifications for the emplacement of rejects by high density slurry were developed according to site specific aspects as outlined below:

- The Metropolitan Mine layout has a range of potential voids for filling. These include:
  - abandoned mine roadways accessible by mine personnel;
  - abandoned mine roadways inaccessible to mine personnel but accessible by fill depending on flow characteristics;
  - limited access to previously extracted longwall areas; and
  - future longwall areas.

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- the range of pumping distances required was between 500 and 8 000 m;
- liquefaction of the emplaced fill (for example by earthquake) was considered an unacceptable risk if uncontrolled flow could endanger mine personnel. The risk of bulkhead failure resulting in inrush that may endanger mine personnel was also considered an unacceptable risk;
- the risk of pipe blockage would need to be minimal;
- the risk of groundwater contamination after mine closure should be negligible;
- the environmental site constraints of noise and dust must not be exceeded;
- the Metropolitan surface footprint is extremely small, being constrained by topography which precluded a large fill preparation facility (no ball mills; no grinding facility; no dewatering facility; no batch plant; and no large pumps);
- water usage should be minimised;
- no introduction of additional material such as flyash;
- emplacement could not disrupt mine production; and
- the emplacement method should be cost effective compared with trucking off site ($12.50/t).

These site specific limitations drove the fill specifications, which include:

- a friction loss of less than 4 kPa/m was initially targeted to achieve the pumping distances required;
- low free water release, target moisture content of less than 30%;
- pumping capacity of at least 125 tph;
- continuous process - not a batch process;
- the particle size distribution would need to be achieved without using milling or grinding processes;
- an emplacement strength (UCS) of at least 100 kPa to eliminate the liquefaction risk in accordance with industry best practice (Le Roux, *et al*., 2004);
- a beach angle[1] of 3 to 4° to facilitate flow into inaccessible areas;
- non-settling to minimise risk of pipe blockage, and
- additives must not be potentially harmful to the environment.

INDUSTRY EXPERIENCE

Emplacement of coal mine rejects had previously been conducted at Walsum Colliery in the Ruhr Valley, Germany using a goaf cavity filling technique developed by Deutsche MontanTechnologie (DMT) in conjunction with Ruhrkohle AG (Mez and Sill, 1992; Mez and Schauenberg, 1998). Walsum generated a pumpable paste from the fine tailings fraction of the coal mine rejects mixed together with flyash from external sources. The paste was pumped underground and emplaced behind the longwall supports in trailing pipes as shown in Figure 1. Unfortunately the colliery closed in 2006.

An investigation of other operations involving waste disposal in underground workings was conducted. This included:

- metalliferous tailings into stopes as cemented backfill at Lisheen Mine (Ireland) and St Ives Gold mine (Western Australia);
- waste product into old disused underground workings as low strength backfill such as Boulby Mine (UK);

[1] Beach angle is a term borrowed from tailings dam impoundment. It refers to the slope created from settling of particles after discharge. Typically the 'beach' slopes from the discharge point to the middle of the impoundment. In the context of the Metrop backfill project, beach angle is the slope created from the settling of particles following discharge from the pipe - it (along with other factors) governs how far the fill will flow along a roadway from the discharge point before the discharge point becomes choked off.

- flyash waste disposal into coal mine longwall goaves at Carbisulcis mine, Sardinia, Italy; and
- use of backfill for spontaneous combustion and subsidence control using combinations of sand, coal reject, coal tailings and flyash into Polish coal mines such as Staszic Mine, Myslovice Mine, Pniowek Mine and Borynia Mine.

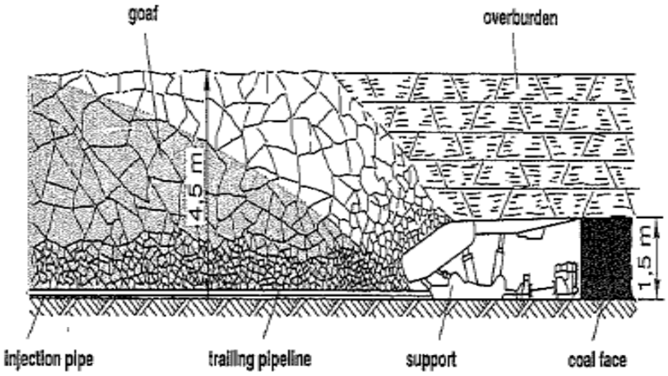

Figure 1 - Goaf filling method - Walsum Colliery (after Mez and Sill, 1992)

An investigation into long distance pumping with cementitious materials was conducted such as 3 km to 7 km flyash-cement slurries at mines such as Auguste Victoria Mine (Germany), 1 km dredged sludge-cement slurries for Haneda airport (Japan) and general concrete pumping technologies from Putzmeister and Schwing (Germany).

The outcomes of these investigations were:

- the cost of grinding and dewatering to achieve the same particle size distribution and moisture content as a metalliferous backfill plant was a major cost component and required significant real estate on the surface;
- a very fine particle size distribution used in metalliferous mine backfill which made for easy pumping would be a liquefaction risk without cement;
- chemical pumping aides were commonly achieving a 40% to 60% reduction in viscosity in both very fine pastes and coarse concretes;
- long distance pumping of coarse and fine particle size distributions was proven and established in various industries, and
- coal mine goaf and roadway disposal of hydraulic fill into coal mines was proven and established.

METROPOLITAN MINE REJECTS CHARACTERISTICS

The material characteristics of the rejects are summarised in Tables 1 and 2. The particle size distributions (PSD) of the various feeds individually and combined are shown in Figure 2.

Figure 3 indicates the PSD resulting from crushing of a sample in a combined Horizontal Shaft Impactor (HSI) and then Vertical Shaft Impactor (VSI). It was considered desirable to achieve a PSD that would not require a ball mill due to the limited space availability within the mine surface facilities. A ball mill would also require a de-watering process step, again requiring additional space and additional processing complexity. The total rejects raw feed is also shown in Figure 3 for comparison. The VSI/HSI PSD shown in Figure 3 provided an initial target PSD for laboratory and field studies. To put the trial mix into perspective, the HIS/VSI trial PSD plot is similar to a pumped concrete which is a mix that is 10 mm aggregate with sand and cement, which is a mix that is regularly pumped long distances in the construction industry.

Table 1 - Rejects material characteristics

	Density (kg/m^3)	Moisture (% w/w (as))	Hardgrove Grindability Index	Unconfined Compressive Strength (MPa)
Coarse Reject	2000	6	62	32
TBS* Reject	1700	19		
Flotation Tailings	1700	70		

* *TBS stands for Teeter Bed Separator. It's a process during coal washing that uses an upward current of water to separate particles. Those particles that have a free settling rate equal to the upward current are held in a state of 'teeter'. What matters here is that the TBS process generates a high percentage of rejects that are sand (1 mm) sized particles.*

Table 2 - Feed throughput and particle top size

	Nominal (tph)	Maximum (tph)	Top Size (mm)
Coarse Fraction	49.5	107.5	50.0
TBS	12.2	36.7	0.8 wedge wire
Flotation Tailings	14.5	29.0	0.35 wedge wire

LABORATORY STUDIES

MCPL commissioned two independent laboratories: Tunra Bulk Solids Handling Research Associates at Newcastle University and DMT laboratory in Germany to provide an initial assessment of flow characteristics.

Laboratory samples were prepared by crushing the coarse rejects to a top size of 5 mm and adding the TBS rejects and tailings according to the nominal feed throughput ratios summarised in Table 2.

The DMT laboratory results indicated that a suspension of one part tailings and 6.75 parts coarse rejects (this is the ratio outputted from the washplant) were pumpable and non-settling. The DMT results for the 5 mm top size mixture indicated that instability could cause a blockage, although none were encountered during the trial. The Tunra results indicated that the rejects sized to 5 mm could be pumped, stopped and restarted.

Whilst there were clearly aspects of the suspension that required further investigation, MCPL were sufficiently encouraged by the laboratory results to proceed with surface field trials.

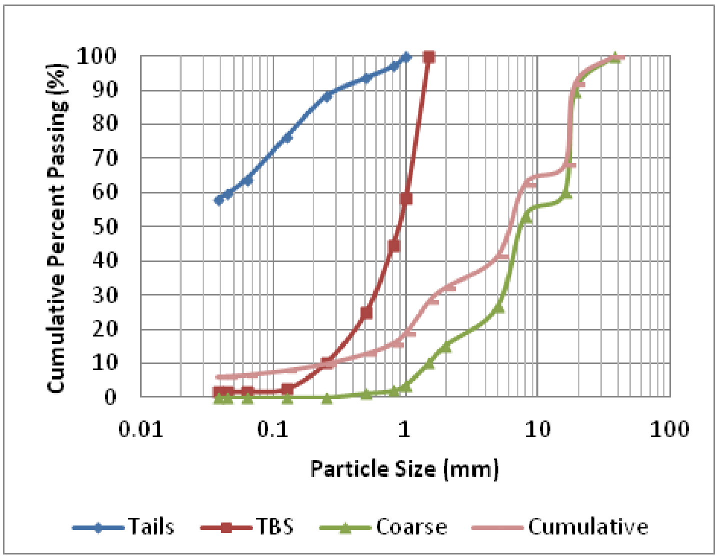

Figure 2 - Particle size distribution - coarse rejects, TBS, tailings and combined

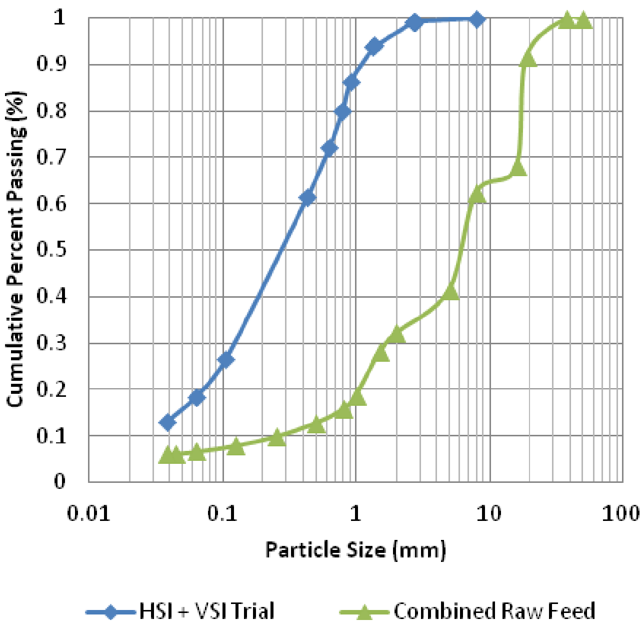

Figure 3 - VSI and HSI particle size distribution compared with unprocessed rejects

FIELD TRIALS

A field trial was conducted at the pit top facilities at Metropolitan Mine. A 500 m long tortuous 100 mm diameter pipe range was constructed as shown in Figure 4. The pipe circuit included two sections of 50 m that could be separated to test settling/restart for various residence times. The plant was composed of: a mixing hopper; pug mill; agitator tank; and pump as shown in Figure 5. The backfill plant had a swing tube pump mounted under an agitated tank which could hold up to 2.3 m^3. The pump was a swing tube positive displacement pump with the following features:

- stroke of 1.219 m stroke (48");
- a line bore internal diameter 0.1524 m (6");
- an hydraulic cylinder internal diameter of 0.0672 m (3"); and
- a variable speed hydraulic drive from 0 to 52 strokes per minute.

The field trials were designed to establish the operating envelope in terms of PSD; moisture content; pumping speed; density; friction loss; pipe retention times; and effect of pumping aid. In addition, qualitative assessment of flow characteristics after discharge onto the ground and potential penetration into caved strata were conducted.

The field trials established the following operating flow characteristics:

- Friction loss within a 100mm pipe range: 2 to 6 kPa (nominal 4 kPa);
- Moisture content (%w/w as): 15 to 36% (nominal 30%); and
- Density (kg/m^3): 1500 to 1700 (nominal 1600);
- Pipe retention time: up to 9 days.

The use of a pumping aid (EZ Flow from Cellcrete Australia Pty Ltd) in the range 50-150 mL/t was found to reduce friction loss and provide suitable pipe lubrication. Observation of flow after discharge from the pipe indicated that the slurry would flow over the ground with a beach angle of between 3^o and 5^o.

A trial of emplacement into a dam composed of loose rocks (Figure 6) to simulate caved strata indicated that adequate penetration should be achieved. Measurement of the shear strength of the slurry emplaced within the dam versus time was conducted.

Figure 4 - Surface field trial layout

Figure 5 - Field trial plant

Figure 6 - Dam composed of loose rocks

The results shown in Figure 7 indicated that the drained shear strength of the emplaced slurry reached 50 kPa after approximately 75 days and continued to gain shear strength to approximately 95 kPa after 140 days. The results were considered adequate to eliminate the risk of liquefaction.

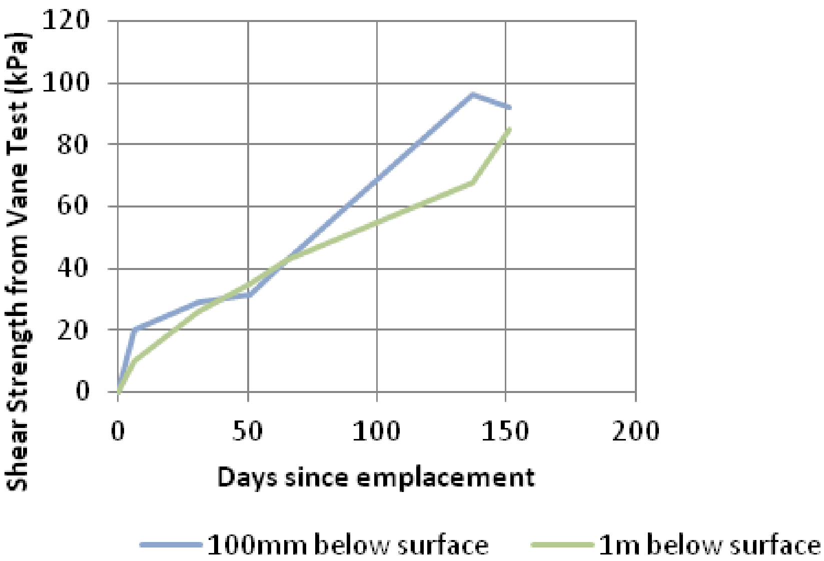

Figure 7 - Shear strength versus time - surface emplacement trial

PILOT UNDERGROUND PLANT

Following the encouraging field trials, the plant used in the field trial was relocated to its final position adjacent to the CHPP as shown in Figure 8. At this stage the totality of rejects could not be emplaced underground until the remaining elements of the Metropolitan expansion project were completed. This would include an upgrade to the power facilities and CHPP upgrade to include a rejects comminution circuit. Prior to completion of the expansion project, the pilot plant included refinements including automation of the feeds; addition of a sizer to reduce the coarse material to -15 mm and modifications to the hydraulics. The feed combination of 50% TBS and flotation tailings and 50% coarse rejects sized to -15 mm represented a combined particle size distribution that would be achievable from the rejects comminution circuit once commissioned.

Figure 8 - Pilot plant layout

The PSD using a mixture of 50% from the sizer and 50% TBS and tailings provided a PSD consistent with that shown in Figure 3, in other words, that could be achieved without a grinding or milling circuit.

Underground emplacement commenced in May 2011 into disused workings. The underground pipe range extended for 890 m. Visual observations of the underground emplacement included:

- flow of over 200 m from the discharge point (unable to access workings beyond this distance);
- minimal segregation at a distance of over 200 m from the discharge point; and
- penetration through a roof fall that otherwise choked the roadway.

The PSD successfully emplaced underground (using 50% sized to -15 mm and 50% TBS and flotation tailings) compared with that obtained from a combined VSI and HSI crusher and compared with the unprocessed rejects is shown in Figure 9. The underground emplacement results confirmed that a high density slurry coarser than that generated by employing a comminution strategy that excluded a ball mill or grinding circuit, could be pumped underground.

At the end of October 2011, MCPL has emplaced over 15 000 tonnes of rejects underground which has taken some 500 trucks off the road. MCPL will proceed to full scale plant commissioning towards emplacing all rejects underground.

POTENTIAL FUTURE APPLICATIONS

As found in Poland, once the technology was installed, the use of low strength backfill found a number of uses including, control of spontaneous combustion, subsidence mitigation, and goaf ventilation reduction.

Another use identified was to use the backfill plant and reticulation system, and to add cement to make construction materials. It is envisaged to replace conventional concrete use underground with a lower strength mass concrete made from reject and delivered efficiently via the backfill underground reticulation pipeline. This would lead to mass concreted roadways and bulkheads at <$100 /cu.m. This would result in operational costs savings including eliminating scrapers, road repairs, reduced travel times, less wear and tear on underground vehicles, and higher factors of safety on bulkheads. A recent study for another coal mine identified up to $50 M in savings if concreted roadways were implemented at the start of a 20 year mine life.

MCPL will investigate the emplacement of rejects into the goaf behind an operating longwall using methods similar to that used at Walsum Colliery (Figure 1) to potentially reduce surface subsidence. The general concept is to construct a cemented rejects pillar approximately mid-panel that will bear a proportion of the overburden load that would otherwise be redistributed to the longwall abutments, thereby reducing subsidence.

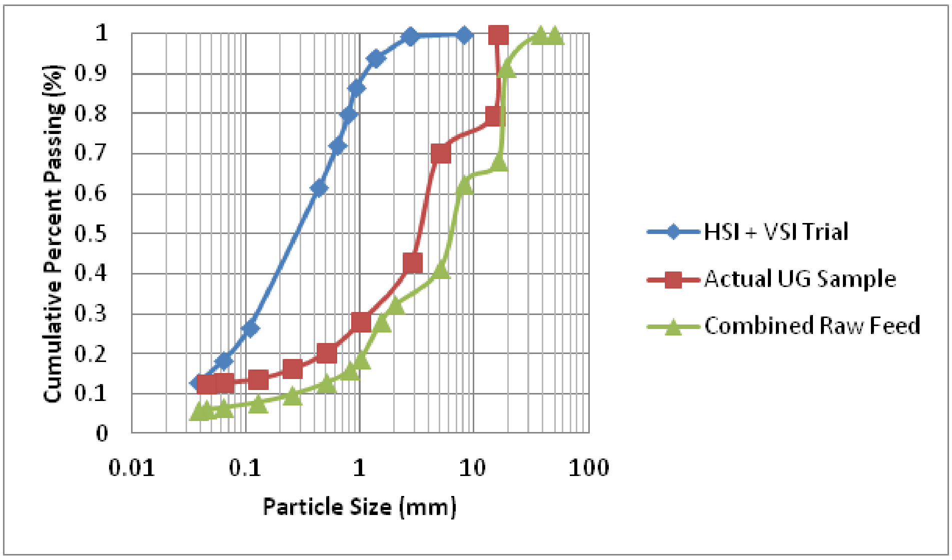

Figure 9 - Particle size distribution - rejects emplaced underground

CONCLUSIONS

The underground emplacement of coal mine rejects has been successfully developed to pilot underground phase and is expected to advance to full scale emplacement of all rejects underground at Metropolitan Mine.

The application is expected to progressively reduce the number of coal rejects trucks through Helensburgh, eventually eliminating the trucks by the end of 2015. MCPL intends to further develop the technology to potentially reduce subsidence by emplacement behind the operating longwall face.

In addition to the application at Metropolitan, based on overseas experience the technology has a range of other industry uses. These include: as a construction material; mitigation of spontaneous combustion events; goaf ventilation improvement; confinement of pillars for subsidence control; and use in standing support. Whilst the operating cost is three to four times more than typical surface emplacement, these applications may be cash positive since the backfill plant is relatively low capital cost.

The adoption of this technology not only replaces surface disposal, it provides a coal mine with a new hydraulic media and distribution system.

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