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Alternative excavation methods in undeground coal mining

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ALTERNATIVE EXCAVATION METHODS IN UNDERGROUND COAL MINING

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ABSTRACT: With the recent turbulent nature of the global financial environment, project drivers have been challenged with the emphasis being placed on methods to gain early access to ore bodies, rapid development techniques, lower capital costs and reduced labour requirements to name a few. Recently work commenced on a project that is challenging the norm and implementing an alternative excavation method into the Australian coal mining industry by the use of a tunnel boring machine. The tunnel boring machine will mechanically excavate both the Conveyor Drift and Transport Drift at Anglo American's Grosvenor Mine in Moranbah, Queensland. This paper will review this project and provide technical and operational insight into some of the challenges faced in implementing this and other alternative excavation methods in the Australian underground coal industry.

INTRODUCTION

In recent times, a number of underground coal mine development projects in the Bowen Basin region of Queensland Australia have been undertaken. These projects have been undertaken through varying strata conditions with differing excavation methods, support requirements and differing pieces of equipment.

With the recent turbulent nature of the global financial environment, project drivers have been challenged with an increased emphasis being placed on methods to gain early access to coal, lower capital costs and reduced labour requirements.

The development of safe and effective alternative excavation methods that comply with regulatory requirements is a challenge the industry needs to embrace. Given the current cost pressures being faced by the mining industry, some alternative excavation methods offer the potential for longer term sustainability and rapid development of resources.

Noteworthy projects that have included varying excavation methods in remote and challenging environments include:

- Carborough Downs Drift Development, Australia – Carborough Downs Coal Management
  Construction of 3 drift entries through drill and blast excavation.
- Kestrel Mine Extension, Australia – Kestrel Coal (Rio Tinto and Mitsui joint venture)
  Drift development using modified roadheaders supported by a sliding floor as Donnelly, Ramage *et al*., (2011) explained.
- Ghaghoo Diamond Mine Sand Tunnel, Botswana – Gem Diamonds
  Construction of a decline through the sands of the Kalahari desert in Botswana, Buthelezi (2012).
- Ok Tedi Mine Drainage Tunnel, Papua New Guinea – Ok Tedi Mining Limited
  Construction of a 5.3 kilometres tunnel for the purpose of dewatering the open pit mine. The main tunnel development was driven by a 5.6m diameter tunnel boring machine (TBM).

Building on the success of these projects and lessons learnt during their execution, work has recently commenced on a project that is implementing an alternative excavation method into the Australian coal

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mining industry through the use of a TBM. The TBM will mechanically excavate both the Conveyor Drift and Transport Drift at Anglo American's Grosvenor Mine in Queensland's Bowen Basin.

GROSVENOR MINE PROJECT

Project background

The Grosvenor Mine project (Grosvenor) owned by Anglo American Metallurgical Coal (Met Coal) includes the construction of a new underground coal mine and surface facilities on the northern boundary of the town of Moranbah in the Central Queensland Bowen Basin coal precinct. The project covers the development of an underground longwall mine and associated surface infrastructure to deliver coal to the existing Moranbah North Mine (MNM) (owned by Met Coal) which is located to the North of the Grosvenor site.

The project is the development of a single longwall operation at Grosvenor, producing up to a maximum of 7.5 Mtpa Run-of-Mine (ROM) coal with the average ROM being 6.5 Mtpa. Coal will be transported to MNM via an overland conveyor and processed through an upgraded MNM Coal Preparation Plant. Product coal will be loaded out via the Moranbah North rail facility.

The Grosvenor mine project is planning to mine the Goonyella Middle seam, which forms part of the Moranbah coal formation, by conventional longwall methods. The coal handling system will deliver coal onto a new overland conveyor belt for processing in the existing Moranbah North coal preparation plant.

The underground development scope consists of the construction of a 762 m long 1:6 gradient conveyor drift, a 993 m long 1:8 gradient transport drift, development of the pit bottom area roadways (nominally 2,520m of driveage), and the development of the first longwall tailgate (nominally 10,550 m of driveage).

The contract to undertake the underground development works was awarded in 2012 and will commence excavation of the drifts in the 4^{th} quarter of 2013. This paper will discuss the adopted excavation method and the challenges faced in implementing a TBM into a Queensland coal mine.

Excavation method

The original tender for the development of the underground drifts contemplated the construction using more traditional methods of excavation for coal mine drift development. It was observed in the tender drawings that the nominated ground support for the drifts (primarily rock bolts and shotcrete) was extensive and would lead to a longer construction period due to increased cycle times and slower advance rates and thus an increased cost to construct the drifts. Given these factors an alternative method to excavate the drifts using an earth pressure balance EPB TBM (refer Figure 1) was proposed in lieu of the more traditional Roadheader excavation method.

Following due diligence on the TBM excavation method by Met Coal, the parties worked together through 2012 and the beginning of 2013 to bring the concept of TBM driven drifts into reality. As a result, the two drifts at Grosvenor will be developed with a 135 m long, 8 m diameter EPB TBM commencing in the 4^{th} quarter of 2013. The drifts will be fully lined with concrete segments on advance and waste material will be transferred to the surface via a conveyor system assembled in the drifts. The major technical specifications for the TBM are summarised in Table 1 – TBM Specifications.

The use of a TBM to develop coal mine drifts is not unique to the Grosvenor Project. Evidence of the use of TBMs to develop coal mines is referred to in '*White, (1978)* and *Palmer, (1985).'*

Regulations, the law and construction

For the Grosvenor project the applicable legislation is the Queensland Government's Coal Mining Safety and Health Act (CMSHA), 1999 (Act) and the Coal Mining Safety and Health Regulations (CMSHRA), 2001 (Regulations) as enacted at the time of construction activities being undertaken. As a TBM has not been used in the development of an underground coal mine in Queensland, the initial effort of the project team would be to ensure compliance of the machine to the legislative requirements.

A number of factors needed to be considered during this process including ground support, gas exposure and management, ventilation, dewatering and construction. The following outlines what was

identified by the project team and the solutions put in place to manage the identified risks and hazards to ensure compliance with the applicable laws.

Figure 1 - Assembled EPB TBM

Table 1 - TBM specifications

Bore Diameter	8.0m
Cutterhead Speed	0 - 3.2rpm, constant torque range 3.3 – 6.4rpm, constant power range
Maximum thrust	53,018 kN
Stroke	850mm
Cutters	50, 17" wedge lock, back loading
Power Supply	11kV

Ground support

A common practice for underground coal mine development in Queensland, is to commence the initial part of the drift construction as a cut and cover tunnel. Figure 2 and Figure 3 show the initial box cut excavation and the commencement of construction of the Armco tunnel which would subsequently be backfilled and have fibrecrete sprayed internally at the launch location.

Due to the anticipated ground conditions it was viewed that the ground support for the remaining drift lining would be a fully lined precast concrete from the box cut to the target coal seam interface. The benefits of this chosen support are numerous but it primarily added the benefit of a 50 year drift life with no necessity for remedial or rehabilitation works during the life of the mine. The precast concrete lining further provided a ground support system that would limit the possibility of gases being present in the drift both during construction and in operation.

The ground support system pre-cast concrete segments is the same type of construction used in civil tunnel construction around the world, with the ground support having a considerably extended life over traditional coal mining support mechanisms. As referred to in *'White, (1978)'* the support system used in the TBM development of the West Cliff Mine in New South Wales, was rockbolts and mesh making the Grosvenor drifts the first precast concrete lined, TBM excavated drifts in Australia.

Gas management

The drifts at Grosvenor traverse a number of stringer (coal) seams as they head for the Goonyella Middle Seam (target seam). It has been identified that that there is potential for high levels of gas to be present in these seams and the gas if present needs to be managed effectively to minimise the risks. Given this concern the excavation of the drifts with an EPB TBM offers a significant benefit as the sealed chamber at the front of the machine will allow any gas that is encountered in the cutting area to be contained in this space.

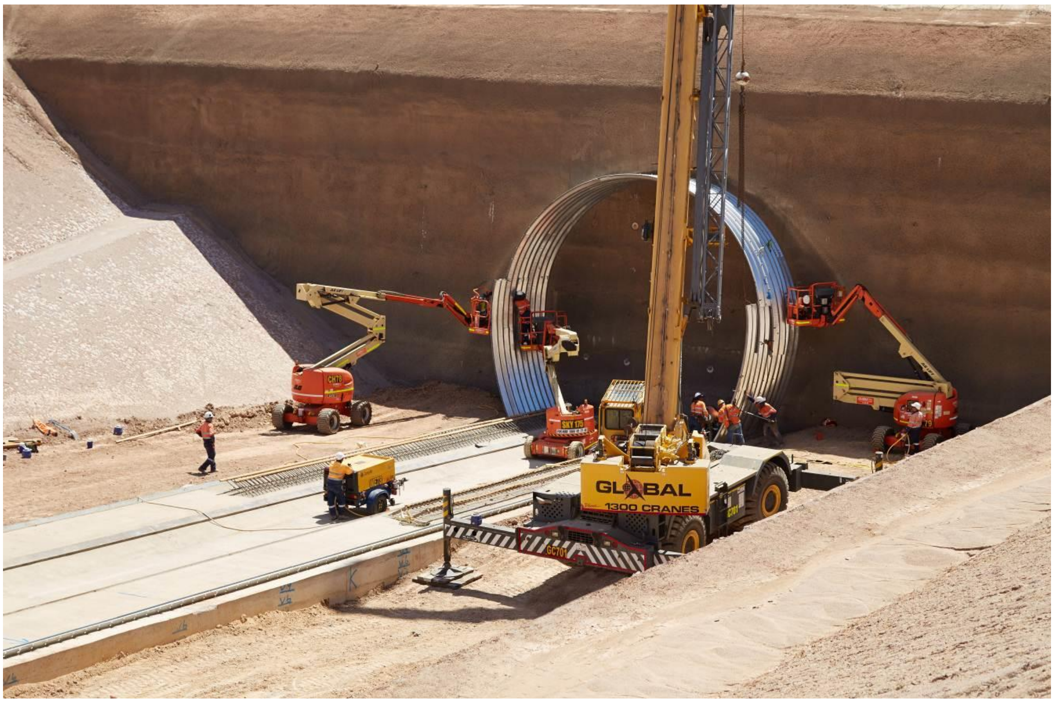

Figure 2 - Construction of the Armco tunnel at Grosvenor

Figure 3 - Face preparation for TBM launch

Subsequent lining of the drift will ensure the gases that would usually be present in these stringer seams is contained behind the precast concrete and have no effect on the operation. With the use of an EPB TBM, the full sealing of the inherently poor ground conditions from the work environment and the improved development rates have a significant reduction on the time taken for drift development, and therefore overall project risk. The EPB chamber and screw conveyor (refer Figure 4) are pressurised during excavation.

Figure 4 - Rear of forward shield and cutter head

Ventilation

Each drift will have exhaust ventilated through a single 1400 m diameter steel duct which will be continually installed as excavation is taking place. Each drift will be connected to a single fan equipped with gas monitoring systems to comply with legislative requirements.

The duct will have an extension tube located in the last duct at the face to allow the maximum ventilation effort to be extended to within 2 m of the face during the cutting cycle. A stuffing box is installed below the screw conveyor, which removes any gas prior to material being loaded onto the conveyor. The vent duct will be installed in-bye of the boot end and above the conveyor alignment to maximise the trafficable envelope in the drifts.

Dewatering

With the design of the EPB TBM, any ground water that is encountered at the face is incorporated with the cuttings and removed along with the excavated material through the screw conveyor system. Water inflows into previous tunnelled areas will be eliminated by the grouting of the installed segment rings.

The chosen pumping system to support dewatering activities has taken into account the continuous decline of the drifts which is not normally present in civil tunnelling applications. The change is not significant but needs to take into account the additional head that is present as the depth of cover increases with the face advance.

KESTREL MINE EXTENSION PROJECT

Project background

The development of two drift access tunnels on the Kestrel Mine Extension (KME) Project in Emerald, Queensland, Australia was completed during the period 2009 to 2011. The works package consisted of the construction of two drifts, a conveyor drift and transport drift, followed by the inseam development and subsequent panel development for a longwall coal mine.

The drifts at KME are exclusive of each other, designed with different grades and close inseam interfaces at the German Creek coal seam. As a result of this, the drift portals are located a significant

distance apart on the surface. The KME drift design provided by Kestrel Coal is generally described as follows:

- Conveyor drift (Arch Profile) gradient 1 in 6, nominally 6.5 m wide x 5.2 m high x 1560 m slope distance from the start of the box cut to the inseam phase interface; and
- Transport drift (Arch Profile) gradient 1 in 8, nominally 6.0 m wide x 4.9 m high x 1870 m slope distance from the start of the box cut to the inseam phase interface.

A number of important factors needed to be considered during the tender period for this works given some of the constraints imposed on the works. These constraints included:

- No cross passages included in the design
- Construction through multiple coal seams
- Compliance with the Coal Mining Safety and Health Act and Regulations

It was established that to deliver the requirements of the scope of work and contract, a method that would deliver completed drift as the face advanced was what was required. The basic construction principle carried forward was to provide a completed drift cross section within 30 m of the advancing drift excavation heading. This would ensure no delays to subsequent work activities once the drifts were complete.

The final drift construction methodology proceeded with the major excavation equipment comprising of a S200MA roadheader, combined with an integrated ground support system. It was further concluded that to achieve the desired outcome systems that minimise delays to the face advance needed to be developed. The systems identified as integral to the success of the chosen method included:

- Machine capable of excavation and supporting to eliminate place changing at the face
- A continuous material handling system
- Method of extending the ventilation with minimal disruption to the works
- Pavement installation method that would work concurrent to the face advance.

Excavation method

The equipment selection and design for the works required due consideration of industry regulations, codes of practice and project specific requirements and general constraints associated with the nature and environment of the work.

A significant influencing factor in the equipment selection and design was the requirements of the CMSHR. The CMSHR along with the recognised standards stipulate the controls that must be placed on equipment operating in an underground coal mine. The stipulated requirements meant that the majority of the underground equipment planned to be used to construct the drifts would require significant modifications prior to the works commencing.

To comply with the CMSHR for explosion risk zones (*State of Queensland, 2011)*, it was necessary to ensure that any piece of equipment that operated in-bye of the last installed ventilation duct complied with the requirements of an Explosion Risk Zone 1 (ERZ1). Equipment operating on the out-bye side of the ventilation duct was to comply with the Negligible Explosion Risk Zone (NERZ) requirements.

A critical aspect was to achieve a construction methodology that minimised the time taken to change from one activity to another. The ability to have drift construction activities carried out concurrently provided the real advantage of the system to the project.

The Roadheader S200MA was fitted with a shotcrete boom and a roof bolting boom which satisfied the excavation and ground support design requirements. A benefit of the modified Mitsui S200MA is its capability to excavate, bolt and fibrecrete the drift heading without the introduction of supplementary equipment.

As part of the nominated support requirement, fibrecrete needed to be installed for most support types for the length of the drift. Fibrecrete was sprayed using a specifically designed spray arm assembly which was mounted onto the S200MA Roadheader. Fibrecrete was delivered to the Roadheader via a Jacon Midjet which was connected via a series of steel pipes and rubber hoses. Fibrecrete was transported underground to the Roadheader via Jacon Transit Mixers.

The last aspect of the equipment system is the ventilation duct extension and installation arrangements which are fixed to the sliding floor. The system provides for the installation of 6m long 1.8m or 1.4m diameter spiral wound steel ducts to extend the vent system as mining progresses. A telescopic vent duct section located on the inbye end of the sliding floor provides for the ventilation extension between the installed static duct and the moving / advancing duct located on the sliding floor. Additionally the vent duct system extends to within 3m of the excavated face to maintain the zone boundary between NERZ and ERZ1.

Figure 5 and Figure 6 show the bolting boom in operation and the sliding floor looking inbye to the face of the drift.

Figure 5 - Bolting boom in operation

Figure 6 - Precast floor panels and sliding floor looking inbye

CONCLUSIONS

Through technology and innovation advancements, the opportunity to implement alternative excavation methods in the mining industry is becoming a reality. If a robust and well managed feasibility review is conducted of alternative excavation methods, it is possible to pursue the various opportunities of mining through poor ground conditions and subsequently deliver economical solutions for resource development that may otherwise be unviable.

When consideration is given to the matters raised in this paper, the economics of the solution must be tested and if the economic hurdles are met, a decision made as to whether the implementation of an alternative excavation method will deliver an increase in value to undertake the development of the resource.

The bringing together of knowledge from previous experiences on underground metalliferous and civil tunnelling works, has enabled the development and implementation of alternative excavation systems to construct drifts to meet differing project objectives.

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