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POTENTIAL HAZARDS ASSOCIATED WITH MINE FILL

Background

On Monday, 26 June 2000, at about 5.00pm at an underground gold mine in the northern Goldfields of Western Australia, a fill barricade at the base of a stope located towards the bottom of the mine ruptured and allowed a quantity of fill (estimated at around 18 000 m^3) to enter the lower levels of the mine and the decline. The barricade was constructed of specially designed concrete block material to allow free drainage and the fill itself consisted of deslimed mill tailing, again designed to be free draining. A monitoring system was in place to check the barricade and the last positive check was made about an hour before the incident with nothing untoward reported.

Following the incident, the mine was evacuated and three men were unaccounted for when staff checks were made. These persons were a jumbo operator who had been working in the decline below the incident location, a serviceman and an electrician who had both been working in the area of the fill runaway.

Rescue and recovery operations were put in train immediately and the site rescue team and rescue and emergency services personnel from other operations in the area were quickly mobilised along with specialised equipment for use in the rescue. Despite courageous and diligent rescue attempts, the likelihood that the three men have perished in the incident is growing.

This event underlines the need to remind all underground mine operators and managers of the potential hazards which may be associated with stoping systems which use mine fill, particularly where such fill is placed hydraulically. These hazards are relevant not only to those mines which operate filled open stoping systems, but also those using cut-and-fill mining.

The following information is provided for general guidance and does not specifically relate to the fill escape referenced above.

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Fill Design Considerations – Barricades and Bulkheads

It is of crucial importance that hydraulic fill is properly designed with a particle size distribution that allows for free drainage of the fill mass after placement in stopes. It is also important that a system of regular checks is in place to ensure that the design size range of the fill material is maintained during operations. A minor short-term departure from design characteristics may result in impermeable layering of slimes material in the fill, which can impede drainage. This is of particular importance where mill tailing is used as fill material, but is also relevant where natural sands are employed.

In this discussion 'barricade' refers to permeable free draining structure. 'Bulkhead' refers to an impermeable (water retaining) structure; systems may be established to drain water from behind such bulkheads.

The design of fill retention barricades or bulkheads is critical in ensuring that catastrophic fill escapes do not occur. Design principles incorporating free drainage must be used in order to prevent pressure gradients becoming too high to be sustained by any barricade.

Where bulkheads are used, they must be designed to withstand the full (maximum) hydraulic head which may result from a fluid build-up behind the barricade in the event that stope drainage system is impaired. Massive reinforced concrete plugs may be required or, alternatively, special arched and tapered blocks hitched into the rock walls to support the arch may be used, to form specially shaped walls designed to offer maximum resistance to displacement by hydraulic loads. Other designed systems involving a combination of rock fill and high strength cemented fill in the base of the stope are also used.

In this type of design the materials used in the bulkhead wall must be capable of withstanding the worst-case pressures, both as individual elements, and as a complete structure. The strength of interlock between individual blocks, and the shear strength at the abutment between the bulkhead and rock wall must be known.

The construction methods used, and standards achieved, must be appropriate for the ground conditions, size of openings and stope dimensions.

It is important to correctly assess the maximum hydraulic head that may be imposed on a bulkhead or barricade and to use this value in the installation design, as conditions may change during the active life of the installation. Potential for variation to design conditions can occur through:

- Blockage of the systems used to drain water from the stope.
- Unidentified connections may exist between one stope and another excavation further up-dip, which can result in the maximum potential head rising to the top of the up-dip excavation. In this regard, development holings, drill holes and natural or mining induced cracks, openings or porosity in the rock can become influential factors.
- Blasting adjacent to newly placed and undrained fill can also cause problems due to vibration-induced rises in the water table within the fill, causing rises in hydraulic head and the development of a thixotropic mixture which will flow easily. Similar conditions can arise from seismic events within or adjacent to the mine and even from large-scale collapses of ground within a partially filled stope.

- Even when fill is fully drained and consolidated, there exists the possibility of re-charge from unexpected groundwater inflows, flood or unexpected rainfall events. Systems need to be in place to quickly detect such recharge and to deal with it appropriately. Similarly, regular routine checks of the continued integrity of fill barricades and bulkheads (even in unfrequented areas of the mine) are required.

Potential Mechanism of Failure of Fill Retention Structures

The design of fill retention structures should consider all potential failure modes; eg. foundation failure, side wall failure, loosening of blocks, vibration damage etc.
One of the most hazardous failure mechanisms, piping failure, is often not given due consideration.

In civil engineering (soil mechanics[1]) it has been recognised that a mechanism of failure known as "piping" can cause the sudden and catastrophic failure of dams. This mechanism of failure has been recognised[2, 3] as a possible explanation for several failures of fill barricades in underground mines. Failure by piping involves the gradual washing out or flow of fine fill materials from a small crack or opening in the fill barricade. The erosion of fill materials may start in an inconspicuous manner as a small leak in a fill barricade. If this process is allowed to continue, and the "pipe" formed is sufficiently stable, it can travel up through the fill mass and intersect any water that may have ponded on top of the fill in the stope. Once this occurs there is a direct hydraulic connection between the water on top of the fill and the fill barricade. This can result in large hydraulic pressures being exerted on part, or all, of the fill barricade. If the pressure is sufficiently high it may cause the barricade to fail (partially or completely) and allow the fill materials to flow out in an uncontrolled manner into the underground workings. It should be recognised that even correctly designed and constructed fill bulkheads may fail if loads exceed design.

Hydraulic Fill Systems – Design and Operation

Recent mining industry experience[3] has shown that a range of issues need to be acted on to minimise the potential for barricade failures in hydraulic fill operations, including:

- minimising the fines content (clay size fraction) in the fill
- placement of fill in stopes with the highest practicable pulp density
- minimise the use of fill line flushing water
- not allowing water to accumulate on top of the fill in the stope during filling
- allowing regular drainage intervals between fill pours to remove excess water
- fill barricades should be free draining and may have additional drainage pipes in contact with the fill to enhance water drainage
- fill barricades should be of high quality construction, allowing water drainage but no fill leakage
- regular observations of the upper fill surface (check for water ponding) and drainage barricades (check drainage rates) during filling operations
- record and investigate incidents involving the fill system, particularly water drainage, to determine appropriate corrective action

Managers of underground operations using hydraulically placed fill are strongly urged to re-examine their own systems and processes to ensure that these factors are taken into account and to conduct thorough risk analysis of the filled mining systems in use in their mines.

Analysis should include "worst-case" and "what-if" scenarios as well as normally expected operating conditions. Careful and diligent inspection of current filled voids should also be undertaken to ensure that actual conditions in the mine are in line with those expected, particularly as far as the potential for re-charge of drained fill is concerned.

It is essential to confirm that the full column of hydraulic fill is consolidated and stable prior to starting mining in adjacent stopes.

Reminder on Dams and Plugs for Water Retention in Underground Mines

Although it is not of direct relevance to fill containment structures, it is appropriate to remind managers of underground mining operations of the provisions of Regulation 10.19 – Dams and Plugs.

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STATE MINING ENGINEER

Recommended References

[1] Terzaghi, K and Peck, RB, 1967. *Soil Mechanics in Engineering Practice*, 2nd edition, pp 169-172 and 611-623 (John Wiley & Sons: New York).

[2] Bloss, ML and Chen, J, 1998. Drainage research at Mount Isa Mines Limited 1992 – 1997, in *Minefill '98* (eds: Bloss *et al*), pp 111-116 (The Australasian Institute of Mining and Metallurgy: Melbourne).

[3] Grice, AG, 1998. Stability of hydraulic backfill barricades, in *Minefill '98* (eds: Bloss *et al*), pp 117-120 (The Australasian Institute of Mining and Metallurgy: Melbourne).

Grice, AG, 1989. Fill research at Mount Isa Mines Limited, in *Innovations in Mining Backfill Technology* (eds: Hassani *et al*), pp 15-22 (Balkema: Rotterdam).