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Escapeway Solutions

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ABSTRACT

The requirement for secondary egress from underground workings has long been regulated in Australia. Escapeway systems have evolved from simple airleg rising ladders and timber ladders to steel galvanized ladders and more recently fully enclosed polyethylene ladders.

The polyethylene ladder - Safescape Laddertube - was introduced to the underground mining industry in 2010. It is a cylindrical, enclosed, modular plastic ladder designed for use in underground escapeways and access ways. The design of Safescape Laddertube has many advantages, one of those being that it is enclosed therefore minimizing the risk to climbers of exposure to fretting rock. In 'standard' installations there have occionally been changes in the ground conditions which have resulted in significant fretting or rock burst causing deformation in the Laddertube. In addition there is on occasion a requirement to position an escapeway in ground that has highly stressed or squeezing ground conditions, presenting mines with potential for failure of ground resulting in serious damage to these escapeways.

As a result, Safescape have developed a number of proactive solutions that can be used at the time of installation which will eliminate or minimize the effects of ground that is not 'competent'. These solutions address the need for ground support and eliminate the need for the traditional methods of ground support in a rise such as bolt and mesh, which also means we no longer need to put people in unsupported ground to complete this high risk work.

Despite being a recent development in escapeway systems, Laddertube is effectively being used in a variety of applications, meeting the specific needs of underground mines worldwide.

KEYWORDS: Perlite; Laddertube; Ground support; Polyliner; Raiseliner

1. DEVELOPMENT OF LADDERTUBE ESCAPEWAY LADDER

Legislation exists in all developed mining countries covering the requirement for producing mines to ensure miners working underground have access to an alternative exit from working areas. The primary reason for this is for insurance against a significant ground collapse in the main travelway, which would otherwise result in the entrapment of personnel for an extended period.

In many mines with sub-horizontal orebodies or mines with excessive ventilation requirements such as uranium mines, secondary egress is taken care of by mining multiple primary accesses, multiple shafts or declines accessible from all working areas. Where sub-vertical mines exist with limited strike extent, the most common methods of providing secondary egress include ladderways, raise climbers and headframes with rope hoists.

Ladderways have historically been the preferred choice where the length is limited. Compared to the alternatives, ladderways are more popular because they are simple, self-escape systems and do not require support from personnel on the surface. They are relatively cheap to install and maintain and they are reliable provided that they are maintained in good condition.

Up until recently the most common ladderways found in Australian mines consisted of timber stiles with 20 mm black steel rungs or a simple steel design (Figure 1a). Steel modular caged ladders (Figure 1b) offered additional support to the user in terms of mesh cages and inclusion of rest platforms. One of the problems with these systems is that over time when exposed to ground water they tend to deteriorate. In 2010 Laddertube (Figure 1c) fully enclosed polyethylene ladders were developed as an alternative to conventional steel and timber ladders.

This style of ladderway has proven very popular due to the speed and safety of its installation as well as the fact that it does not corrode when exposed to the highly saline and acidic ground water often found in Australian mines.

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(a) Simple steel design (b) Steel cage (c) Laddertube
Figure 1: The evolution of escapeway ladders.

2. PASSIVE GROUND SUPPORT – A NEW APPROACH

To date Safescape have installed as well as trained site personnel in the installation of laddertube in 9 countries, all of which have a variety of ground conditions. The methodology and solution for dealing with the ground conditions are each dealt with individually to ensure the best possible outcome.

The two main methods of ground support used where the rise is not already supported are Perlite fill and Polyliner support.

2.1 Perlite

Perlite is used as a loose filled surface support medium. It does not add strength to the excavation, but merely stops any scats that become loose from moving. This system is ideally suited to rock that is subject to fretting over time or unravelling due to stress shadow changes. If the issue is low strength rock with a high stress field there are better options including the use of thick poly liners with concrete fill in the annulus.

2.2 A case study – Xanthos Escapeway

Golden Grove Mine site is located in the Mid-West region of Western Australia and has two copper, lead and zinc producing underground mines. It is owned by MMG Pty Ltd. and has been in production since 1990. The mining method used in both underground mines is a combination of vertical crater retreat (VCR) mining and sub-level stope mining. On average, the underground operations extract between 1.2-1.7 mtpa of both copper and zinc/lead based ore. The present mine life of six years is expected to be extended based on the current exploration program.

Gossan Hill, one of the two underground mines at Golden Grove has been in operation since 1998. Over this period a ladder way system has been developed as a second means of egress. Currently this ladder way system extends from the lowest levels of the mine to the surface, a total of 1100m vertical. To begin with the mine developed air-leg raises between levels which were furbished with narrow wooden ladders with steel rungs. As handheld mining became less prevalent there was a shift to raisebore holes, which were furbished with steel caged ladders. Steel caged ladders had been installed in Gossan Hill since 2000 up until 2010. During 2010, as a business development program, Safescape Laddertube was considered as a possible substitute for the steel caged ladders. Cost, time and safety were all taken into consideration when comparing the two.

Based on the comparison it was decided that Safescape would be trialed, with the first ladder way being delivered to site in December 2010 and installed in January 2011. Despite some challenges when installing this initial Laddertube, it was decided to continue using the Safescape product and since that time 11 separate Laddertube escapeways totaling 570m have been installed at Golden Grove.

Like most underground mines, Gossan Hill is ever extending in a downward direction. The challenge associated with this depth is the increased stresses acting on mine openings. One of the inherent advantages of using Laddertube was that the ladder could be installed in a smaller, more stable raisebore hole which would not require any form of ground support. The second round of Laddertube installed at Gossan Hill was in the lowest reaches of the mine in close proximity to impending stoping activities. Even with this smaller more stable raisebore hole, problems were still encountered during the installation phase of the Laddertube. The raise bore hole was fretting, causing scat sized material to dislodge and fall from the walls of the raisebore hole. This was the first time Laddertube had been exposed to such severe ground conditions.

Recommendations were made by Safescape to fill between the outside of the Laddertube and raisebore hole to limit the amount of rock material that could continue to dislodge. The decision was made to continue with the install. Some months after the ladderway had been installed, the Laddertube experienced minor deformation. This was due to small scat sized material falling and accumulating between the raisebore and the outside of the Laddertube. Stoping in the area had already commenced and an acceptable material to fill the void had not been decided upon. This particular escapeway was never filled and shortly after stoping was completed in the area the ladderway was decommissioned as a result of substantial deformation.

The next round of Laddertube installed at Gossan Hill was in the upper region of the mine which had more favourable ground conditions. This allowed time to develop a means to fill the void which would reduce the chance of the Laddertube deforming in other high stressed regions of the mine. Over a six-month period numerous types of material were

trialed, ranging from washed aggregate to aerated concrete. The final product which was decided upon was a light weight, free flowing material called Perlite. The material was relatively cheap and easy to deliver and install.

While Safescape had had success with concrete and cemented sandfill in the past, the downfall of this method is that Laddertube can only handle a static hydraulic head pressure of 2 m of water. This means that concrete can only be poured in 1 m lifts, which makes for a slow and repetitive process to fill longer escapeways.

The Xanthos ore body is a high grade region of ore located between 1000 m to 1600 m below the surface. Mining of this ore body was set to commence late 2013. Prior to any stoping activities the installation of a 200 m long ladderway extending from a neighbouring decline was required. A 1.5 m diameter raisebore hole had been developed between the Ethel and Xanthos declines in 2011. For a 12 month period this hole was used to supply secondary ventilation from the Ethel decline in order to top up the low ventilation flows experienced in the Xanthos area. This system was then later decommissioned when the Xanthos primary ventilation (Figure 2) upgrade was completed. Plans were then set in place to furbish the 200m long raisebore hole in order to create a secondary means of egress for this region of the mine.

Two options were presented to management at the time. The first option was to go with the conventional steel ladder with a mesh protective cage. This option also required the raise to have ground support consisting of steel mesh and bolts. The second option was to continue using the Laddertube product with the additional protection of filling the void with Perlite. The cost comparisons between the two options were similar with the Safescape option representing a 10% saving compared to steel and the time frame available meant that the longer duration of the steel installation was not critical.

As a result, both cost and time were considered minor benefits of the Safescape option. The next consideration was whether the raise could be used to house additional services such as a rising main dewatering pipe. The steel caged ladders had this as an advantage over the Laddertube product as while it could be installed outside of the Laddertube, it would not be accessible for repairs in the future.This requirement was later discarded and this factor was made redundant and accordingly the final and deciding factor was safety. When comparing the safety of the two options the Laddertube product has a clear advantage over the steel cage ladderway, specifically as management considered the process of bolting and meshing the 200m long raise as high risk. Therefore Laddertube was decided upon as the preferred option.

Perlite is the generic name for naturally occurring siliceous volcanic rock. Perlite ore is crushed and screened to various size ranges and then exposed to a rapid heating process taking it up to 850^{o}c at which point the water inside the material vaporizes and causes the softened rock to expand. Tiny glass like bubbles are produced which account for the lightweight and exceptional physical properties of expanded perlite. The resultant lightweight product is a white granular material that handles and pours easily. It provides a quick, inexpensive and permanent method for filling vertical spaces.

Perlite has been the subject of numerous health studies conducted by scientific and governmental research organizations. Significantly, no test result or information indicates that Perlite poses any health risk. Indeed, the uniform result of all health studies points to the conclusion that Perlite and perlite products are safe for consumer use. As with all workplace dusts, Perlite can function as a nuisance dust, so exposure limits are set at those levels. For some workers, exposure can result in temporary physical irritation, discomfort, impaired visibility and enhancement of accident potential. This nuisance dust was encountered during the filling process at Golden Grove and while the irritation caused could be easily resolved by using dust masks or respirators, the installers took the extra step to build a water spray mist to help reduce the dust generated.

2.3 Project performance at Xanthos Escapeway

Installation of the Xanthos escapeway began in the first half of 2013. Due to the additional complexity of installing a 200 m ladder it was decided to use Safescape technicians to complete the entire install as opposed to MMG personnel who had previously been trained in the installation methodology. The technicians arrived on site and completed a three day induction before any work was undertaken. Setting up the site to commence the install required a full day. The time to install the entire 200 m was an additional two days. It then took another days work to anchor and fit out the inside of the Laddertube with rest platforms and a static line fall arrest system. The entire install of the Laddertube itself was completed in less than five days.

The placement of Perlite was undertaken by MMG personnel. This required 230 cubic metres of Perlite to fill the annulus between the raisebore and the Laddertube. The first 100 m section and middle 46m section were undertaken without any issues but during the placement of the bottom 46 m section rock material was dislodged from the walls of the raisebore hole. This caused damaged to the

Laddertube which required remedial work to be undertaken by MMG personnel.

A jumbo was used to chip out the shotcrete seal and bleed the slabs of rock that had fallen and squeezed the Laddertube. Once this rock was removed, the Laddertube was pushed back to its original shape and the seal was replaced before completing the perlite fill process.

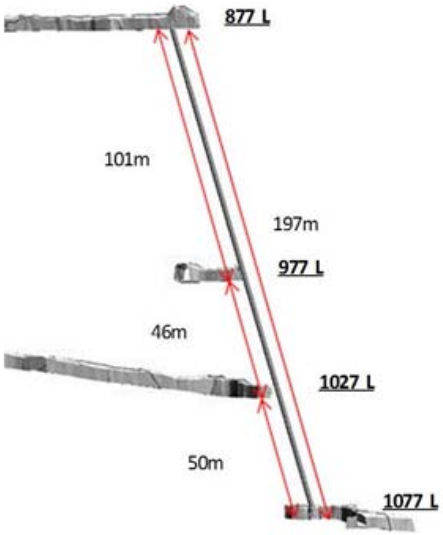

Figure 2: Xanthos primary ventilation network.

While Perlite fill provides mines with a passive ground support solution, in some instances the ground conditions require a more robust solution.

2.4 Polyliner ground support

Highly stressed or squeezing ground conditions or rock bursts, present mines with potential for failure of ground support and can result in serious damage to escapeways. In the mining context, a practical definition for squeezing ground conditions is when the total displacement of an excavation or more specifically, the drive closure reaches at least tens of centimetres within the life expectancy of a supported drive. In general, mine drives are designed to be in operation up to two years (ACG, 2015).

Installing conventional mesh and bolted ground support in escapeway rises is both costly and dangerous, while steel cans installed is a costly and time-consuming process. An alternative to placing individuals in unsupported ground to install ground support which would be quicker and more cost effective than existing solutions was the desired outcome.

Faced with a number of sites which had conditions that were resulting in ground failure and subsequent damage to their escapeway ladders, Safescape made the decision to investigate further a system used in a client's mine in Idaho, USA. This system involves the installation of a thick poly liner followed by a fill around of concrete in a single pass with the escapeway ladder then installed inside the liner (Figure 3).

The liner used by Australian clients is a product produced by Enviropipes. The Enviropipe is dual wall HDPE (PE100) or Polypropylene pipe that are corrugated on the exterior and are smooth on the interior. The standard dimensions are 1050 mm ID, 1216 mm OD, and weigh approx. 215 kg per 3 m length. A larger dimension is available for sites that required them. The modules are high performance and very durable. The pipes do not rust, corrode, crack, shatter or degrade.

The liners are installed by lowering it down the raise and adding pieces, much the same as installation of the Laddertube (Figure 4). Concrete is used to secure the liner in place and support the wall rock. The bottom of the raise is sealed and an initial pour is made to a height of 1m. The concrete is then allowed to cure before pouring the rest in increments. In an installation with a void space of 0.5 m the maximum concrete lift heights allowable to avoid overstressing the pipe are as follows:

- 1050 mm SN8 Enviroculvert – maximum 2.4 m concrete lift
- 1200 mm SN8 Enviroculvert – maximum 2.6 m concrete lift

A safety factor of 1.5 has been used in determining the allowable fill heights. The following assumptions have been used in the design calculations;

i. The maximum differential concrete height around the pipes perimeter is to be no more than 200 mm
ii. The allowable lift heights shall be measured parallel to the pipeline
iii. The concrete is assumed to have a density of 2400 kg per cubic metre
iv. Due to the variable nature of the initial set times of concrete and dependency on admixtures, the initial set time from the time of concrete pour should be requested from the supplier
v. Consecutive concrete pours shall then occur at a minimum of 60 minutes after initial set of the previous pour.

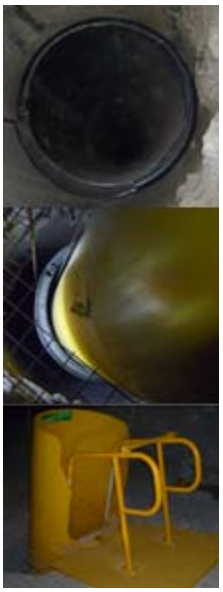

Figure 3: Installation using Polyliner.

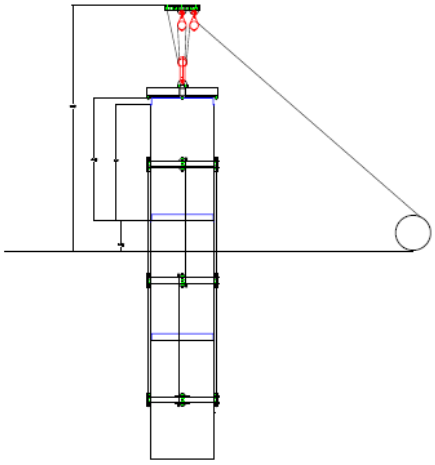

Figure 4: Installation setup for Polyliner.

The installation of polyliners has been successful in providing sites with a cost effective, time efficient solution and importantly, a safe installation process to sites.

3. CONCLUSION

The Australian mining industry is known for leading the world in terms of productivity and safety in underground mining. These escapeway projects are examples of mine operators discarding the status quo and finding a new way to work that both increases efficiency and safety hand in hand. Safescape's polyethylene escapeway ladders are proving a versatile and welcome addition to underground mines in Australia and abroad.

4. ACKNOWLEDGEMENT

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5. REFERENCES

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