New Support Concepts for Hard Rock Mining Applications

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Abstract

A critical safety component for all underground mining is intrinsic and standing support systems. Specifically, tabular hardrock mining exploits a wide variety of deposits that require various methodologies to safely mine the ore material. Several new support systems have been developed in recent years for hard rock applications which have been modified or applied in a variety of ground control applications. These include prestressing devices, improved cribs, and free standing supports. Various standing support and prop-type systems have been designed for hard rock applications with seismic loading conditions to accept prestressing. The prestressing, using water-filled cells, creates an active load upon installation and is considered essential to maintain support during and after the blasting of the mine faces. Heavy seismic activity is also present in these mines and the prestressing units can provide some energy absorption capability to help preserve the integrity of the support. This paper presents an overview of these innovations in support technology.

Figure 1: A historical photograph of miners setting timber posts and beams.

Introduction

For tabular deposits, a wide variety of standing support and cementitious packs are used with mining methods such as longwall mining that are similar to coal mining practices. In fact, timber props and wooden cross members were some of the earliest forms of standing support as shown in figure 1. Although these support products would have limited application in vein deposits common in North America, some of these technologies, particularly the prestressing systems, can be beneficial to stope support that commonly uses a variety of timber posts and headers. A typical hard rock installation of timber post and cross-members used in underground mines is shown in figure 2. A wide variety of prop-type supports has been developed that provide both non-yielding and yielding behavior. Standing support systems use has also been limited due to stability problems at operating heights beyond 2.5 m. Here too, improvements in support technology have been made in recent years, including improvements in timber crib systems which have operated in heights up to 4 m. The performance capabilities of the described systems will be addressed recognizing that they may not be applicable in all conditions in North American hardrock mines.

Figure 2: Traditional timber sets for hardrock applications.

The benefit of pretensioning of tendons is to change the state of stress in rock formations or to provide confining forces that resist movement along fracture planes has been commonly used in mining engineering fields for many years. Pretensioning of long cable bolts, which are a common form of support in hardrock mining, has been particularly difficult because mechanical approaches typically apply a torque to the cable strands creating a spring back effect that reduces the tension after the external torque is removed. Recently, an inflatable metal bladder has been developed that can provide a direct axial pretensioning force to the cable through hydraulic pressure without inducing any torque into the bolt. The inflatable metal bladder is placed between the roof bolt plate and the head of the bolt as shown in figure 3. Laboratory and field tests in cable bolts indicated that the bladder, when simply inflated with water pressure, can create up to 10 tons (89 kN) of preload. As shown in laboratory experiment in figure 4, a quick connect hose is placed on the bladder and filled using air or hydraulic pressure.

Figure 3: Water inflatable prestressing bladder used to pretension roof (cable) bolt.

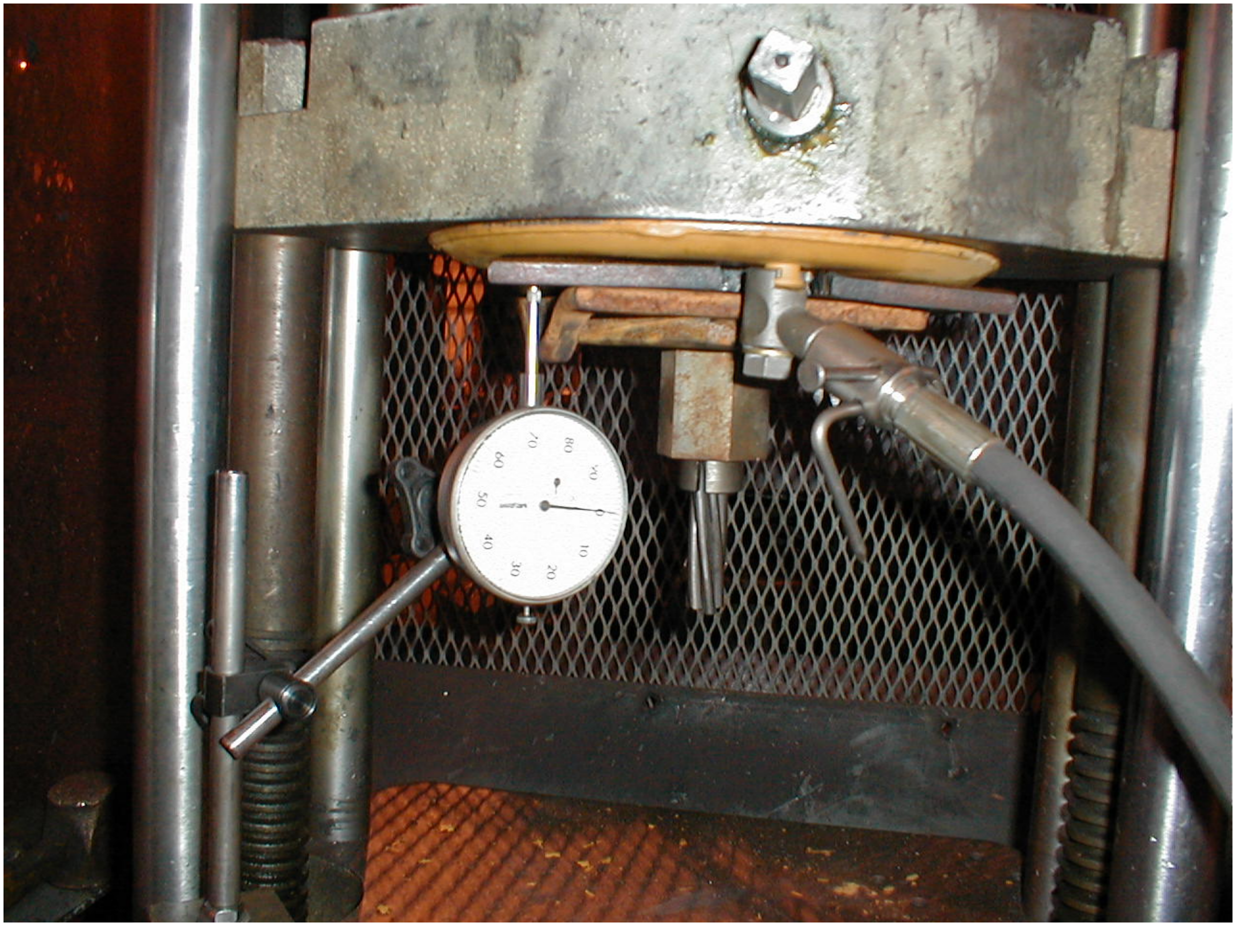

Figure 4: Laboratory installation of pretensioning bladder used in conjunction with a cable bolt.

This same concept has been applied to prestress standing roof support systems that bridge the mine opening from the floor to the mine roof (Barczak et al., 2004). Historically, these supports have been mainly passive supports that generate their load carrying capacity only through the closure of the mine opening, i.e. through roof movement. For timber posts with header boards or cross-timbers, this can mean a few centimeters of convergence will occur before the support generates significant load resistance. Application of a prestressing cell as shown in figure 5 can create an immediate active force against the mine roof and floor. These units can be inflated with up to 12 MPa of water pressure using a portable pressure intensifier to create preloads in excess of 50 tons on a 220 mm cell. The units can be sized to fit any timber post diameter with standard sizes of 140, 160, 175, 190, 220, 260 mm, or fabricated in geometries that can accomated timber sections directly as shown in figure 6. They can also be equiped with headboards to further distribute the load to the mine roof.

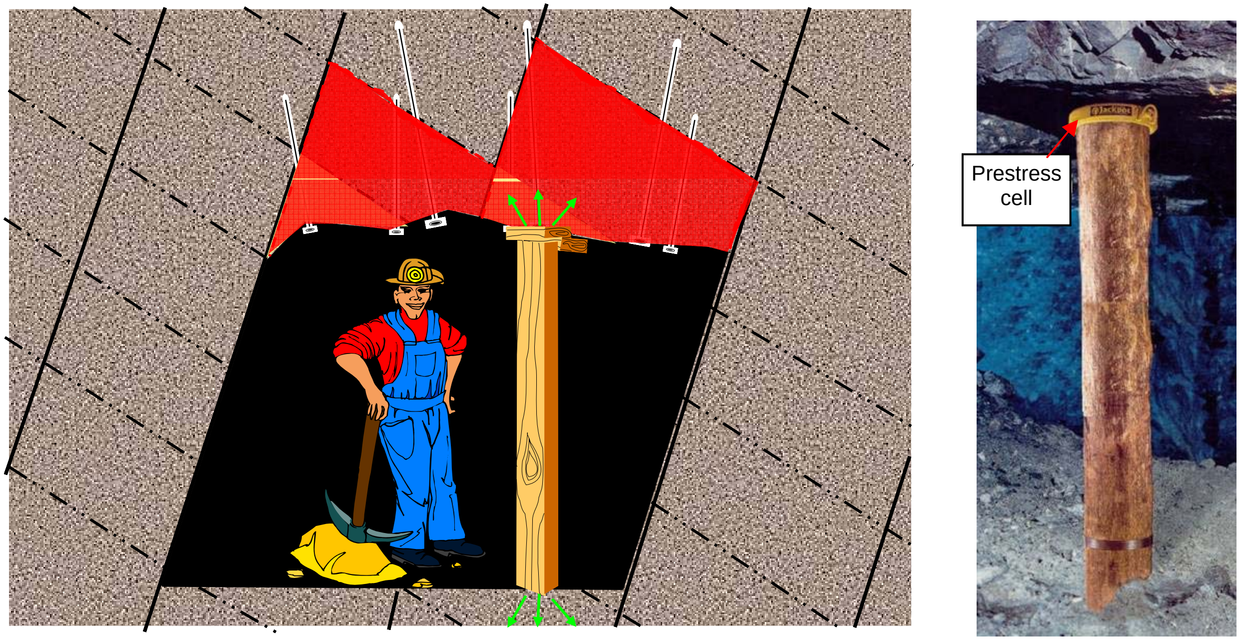

Figure 5: Water inflatable prestressing bladder used to preload a timber post and provide active roof loading to a traditionally passive support.

Figure 6: Water inflatable prestressing bladders can be fabricated in a variety of shapes to accommodate different supports or roof header materials.

In addition to improving roof control, prestressing of these props can be beneficial in ensuring that the props are able to withstand ground reactions and air blast from blasting operations when used in the immediate vicinity of the face, as shown in figure 7. A purely passive support or one that is only lightly preloaded from wood wedges is likley to become dislodged and fall over during nearby blasting operations. Another design of these prestressing bladders can also be enlarged to fit a variety of crib or pack type supports. In this system, two flat sections of metal are welded along the perimeter to create a large cell that with relatively little water pressure can create large preloads. In South African gold mines, these systems are used on timber packs as shown in figure 8. In addition to providing a substantial active force to the mine roof, these devices can be beneficial in prestressing the support structure to remove any initial softness due to construction whereby timber dimensional tolerances or some other issue create a disjointed structure (Barczak, 2005).

Figure 7: Prestressed props can be employed along face line as they can withstand the ground reaction and force from the blasting at the face.

Figure 8: Application of prestresssing bladder on a timber pack.

Summary and Conclusions

Roof support is a fundamental requirement for all underground mining operations. Hard rock mining operations can vary widely depending on the nature of the deposit and require varying degrees of ground support to provide a safe working environment. Blasting and seismic loading can create additional hazards for the rock mechanics engineer who must design an effective support system for these conditions. Nonetheless, the fundamental aspects of rock support remain the same, keep the rock from moving when possible and maintain support as the rock deforms when it is not possible to achieve complete equilibrium.

Several advancements in roof support technology have been made in the past 10 years, providing a host of new products that improves all three measures of support design; namely strength, stiffness, and stability. The cross pollination of support applications has also grown, with supports developed for gold mine applications transformed to coal mine roof support systems and vice versa. However, there is no and never will be a universal support that will be effective in all conditions. The goal remains to match the support performance characteristics with the ground response - that will always require a site-specific design to achieve support optimization.

The purpose of this paper is simply to summarize recent developments in support technology and to introduce hard rock mining engineers to support concepts that they have not been exposed to in the past and is not intended to provide a technical assessment of rock mechanics or support performance. Obviously, these concepts will have varying degrees of application, success, or even failure. However, knowledge of their existence may release the ingenuity that all mining engineers possess which may help to create safer conditions for miners everywhere.

References

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