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Surface support capabilities of freshly sprayed fibre reinforced concrete and safe re-entry time for underground excavations

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ABSTRACT

Sprayed fibre reinforced concrete support is an important component of modern ground support schemes used for stabilisation of underground excavations in rock. In particular, the safe re-entry time after fibre reinforced concrete has been sprayed needs to be considered as it influences the productivity associated with development rates. It is proposed here that the shear strength of the sprayed fibre reinforced concrete matrix is a better parameter to consider than the Uniaxial Compressive Strength of the overall sprayed fibre reinforced concrete material including coarse aggregates. Consequently, a number of sprayed fibre reinforced concrete paste mixes were prepared and evaluated for strength gain. It was found generally that the shear strength of sprayed fibre reinforced concrete pastes increase exponentially during the first 4 h of curing in all sprayed fibre reinforced concrete mixes, except when the pastes included a hydration stabiliser. It was found for sprayed fibre reinforced concrete mixes with accelerator, synthetic fibres and aggregates that an average layer of about 50 mm thickness develops sufficient shear strength of about 20 kPa within about one hour to support the layer mass and a tetrahedral block with 1 m edge lengths. For the same sprayed fibre reinforced concrete layer, it was found that the sprayed fibre reinforced concrete layer and a cubic metre block can be supported within about 3 h and 50 min when the sprayed fibre reinforced concrete shear strength is estimated to be approximately 97 kPa.

1. Introduction

Sprayed fibre reinforced concrete (SFRC) is a surface support technique in which a specially mixed concrete is sprayed at high speed onto rock excavation surfaces to improve rock mass integrity and assist load carrying capacity. The benefits of using sprayed fibre reinforced concrete compared with other ground support techniques have been demonstrated particularly where the rock mass is of poor quality, has short stand-up times and is easily disturbed when attempting to scale or to drill boreholes for the installation of reinforcement and mesh. Wet mix sprayed fibre reinforced concrete is now widely accepted in mines throughout the world, particularly those prone to violent rock failure due to induced stress changes (Villaescusa, 2014). In Australian mines, the use of sprayed fibre reinforced concrete has continued to grow since the late 1980s due to its success in stabilising excavations. The future use of sprayed fibre reinforced concrete will continue and is likely to increase further as mines attempt development within the higher stress regimes and more difficult conditions that generally accompany mining at depth (Villaescusa et al., 2016). In terms of economics, there is also the necessity to minimise development costs. In particular, faster development rates are required with lower ground support costs and increased safety. All of these objectives may be achieved in certain rock conditions using In-Cycle Sprayed fibre reinforced Concrete (ICSC), which in true engineering sense, involves precise mark-up and drilling of face holes (using modern drilling jumbos), blasting (using careful blasting techniques), water jet scaling (using specialised hydro-jetted machines), high quality sprayed fibre reinforced concrete (using modern sprayed fibre reinforced concrete machines) with a timed re-entry into the excavation followed by rock bolting.

Fig. 1 shows the underground mining process for a typical mining development incorporating sprayed fibre reinforced concrete which takes approximately 9 h to excavate a 5.3 m × 5.5 m × 3 m (Width × Height × Advance) tunnel (O'Shea, 2005). It can be seen that the re-entry time is a significant component of the total cycle time.

Re-entry time sometimes presents a conflict between increased productivity and workplace safety. Fig. 2 shows an example of freshly sprayed fibre reinforced concrete that has fallen out due to its own weight. Fig. 3 shows an unstable block falling through a freshly sprayed fibre reinforced concrete layer due to gravity loading. These conditions are examples that need to be considered

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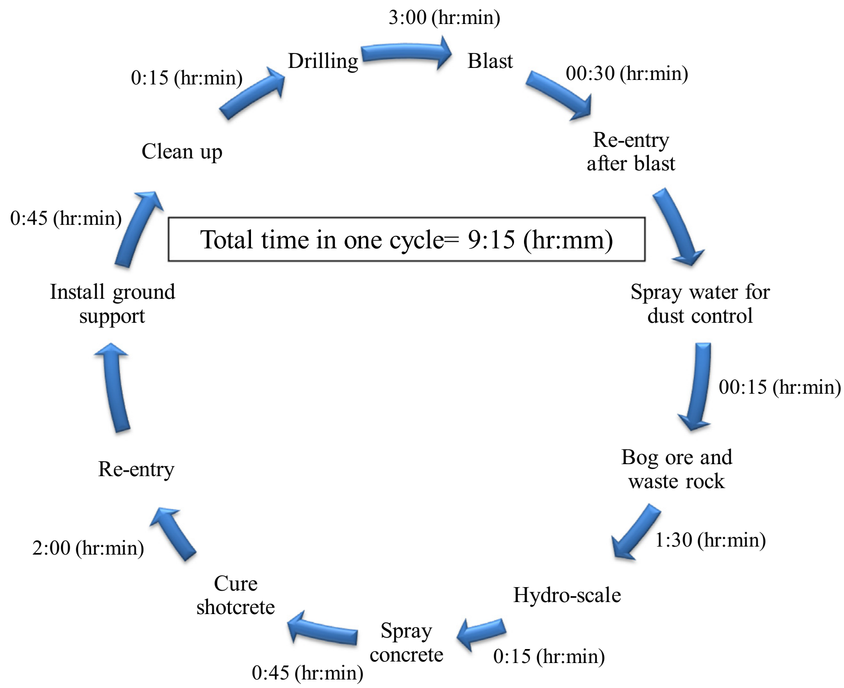

Fig. 1. Underground mining process using ICSC, for a mining excavation having a width of 5.3 m, a height of 5.5 m, a typical advance length of 3 m and a sprayed fibre reinforced concrete layer thickness of 50 mm, (O'Shea, 2005).

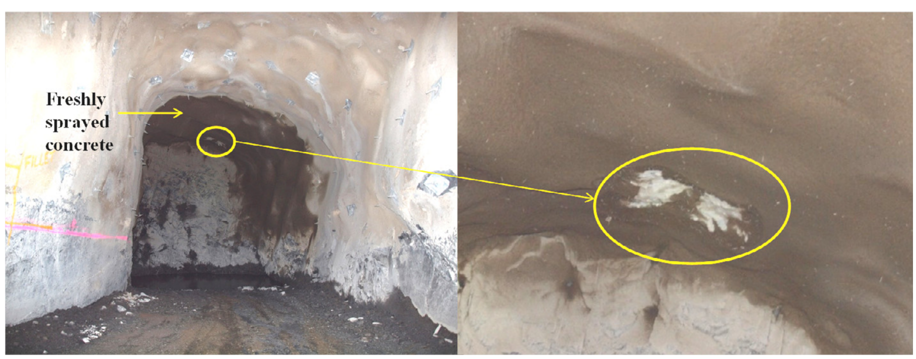

Fig. 2. A freshly sprayed fibre reinforced concrete layer becoming unstable due to its own weight.

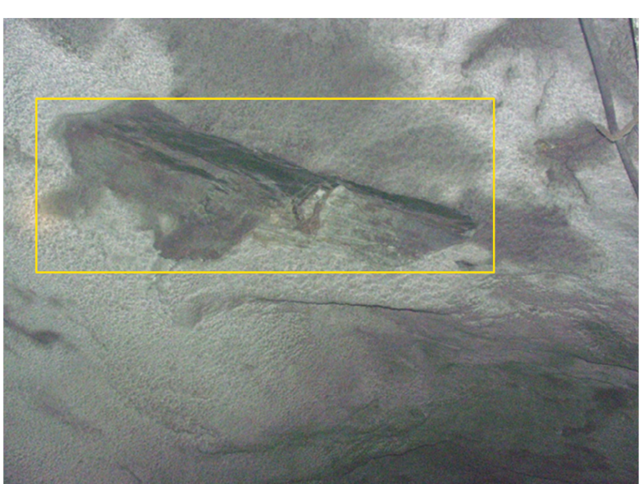

Fig. 3. A gravity driven block failure through a freshly sprayed fibre reinforced concrete layer.

when determining the safe re-entry point underneath a freshly sprayed concrete layer. This paper does not consider re-entry time to highly stressed underground excavations, where de-stress blasting (O'Donnell, 1992) to minimize excavation wall spalling may be required prior to the installation of sprayed fibre reinforced concrete layers.

A review of the current literature does not sufficiently address the issue of re-entry time under freshly sprayed fibre reinforced concrete. Currently, re-entry times range from 2 to 4 h based on the time when the Uniaxial Compressive Strength (UCS) of sprayed fibre reinforced concrete based on penetration resistance reaches 1 MPa (Clements, 2004).

2. Review of sprayed fibre reinforced concrete early strength

Many early strength sprayed fibre reinforced concrete data collected with Meyco needle penetrometer have been published e.g. (Clements, 2004; Jolin et al., 1999; Rispin et al., 2003; Knight et al., 2006; O'Toole and Pope, 2006; Bernard, 2008). Fig. 4 shows the UCS of sprayed fibre reinforced concrete at various curing times determined by the penetration resistance and sprayed beam compression test published by different authors. The implication of