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Investigating the Influence of Underground Ore Productions on the Overall Stability of an Existing Open Pit

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Abstract

In the evolution of mining operations that exploit extensive orebodies to depth there inevitably comes a time where the economics of open pit mining reach their break-even ratio. The consideration of underground operations becomes increasingly important to sustain mine production. This paper describes the process of investigation into the influence of full scale underground operations, using three dimensional finite element analysis, to forecast possible pit failure. The numerical analysis was undertaken using data collected at the Prominent Hill mine in South Australia. Analysis was conducted across the range of excavation steps undertaken within the underground mining operation. This full-stage analysis provides predictive information on stability of the open pit in terms of rock/slope failure. The output provides benefits in safety and production and gives operators and regulators much needed data across the mine life to closure.

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1. Introduction

Geotechnical stability is one of the major challenges of every stage of a mining operation. Geotechnical analysis ensures that the mine design provides an optimal excavation setting in the context of safety, ore recovery and financial return. Beck [1] identifies the importance of large scale instability issues and how they, if not foreseen, can render a mine infeasible or prevent planning objectives from being reached or delayed.

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Conventional geotechnical analysis assesses slope stability using probabilistic and static/limit equilibrium analysis. Where these methods have been successful in the past, they have been unable to accurately describe the effects of energy dissipation due to mining progression throughout an entire mining operation [2].

More advanced analysis methods such as numerical analysis can provide detailed response of rock mass to a various loading conditions and excavations. One of the most robust and widely used numerical analysis is Finite Element Analysis (FEA) which is a continuum based method. In particular, three dimensional FEA can accurately capture behavior of rock and rock mases under various loading conditions in a complex geological setting. Additionally, by calibrating rock movement against past monitoring data of a mine, predictions of future movement of rock mass due to mine progression can be made [3]. In the current study ABAQUS software was used, which can implement detailed variation of geological sections, complex excavation geometries and sequences as well as in situ stress fields. This paper specifically investigates the interaction of the Malu underground stope production on the above Malu open pit at Prominent Hill, owned by OZ Minerals, by modelling pit progression from year 2006 to the expected end of mine life in year 2028.

1.1. Prominent Hill operation

Prominent Hill is a major copper-gold deposit that is situated 650 kilometers North West of Adelaide. Minotaur Exploration Limited discovered the deposit in 2001, which was then bought by Oxiana Limited in 2005. This company became Oz Minerals in June 2008 after it merged with a fellow Australian based mining company called Zinifex Limited. The mining operation consists of the Malu open pit mine, the Ankata underground operation and the Malu underground operation. The mining lease area also accommodates a grinding and flotation processing plant as well as a permanent village for the employees.

Prominent Hill is an iron oxide hosted copper-gold (IOCG) deposit with geological characteristics similar to Olympic Dam and Carrapateena in South Australia and Ernest Henry in Queensland [4]. Mineralization consists of copper-gold breccia which makes up to 80 per cent of the known mineralization and can be broken down into four main types[5]. These are chalcocite-bornite, bornite-chalcopyrite, chalcopyrite-bornite and chalcopyrite-pyrite.

It is uncertain how the development of the Malu underground will affect the surrounding rock mass or the overlying open pit stability. Whether the excavation of sub level open stoping will play a part in slope stability is uncertain. OZ Minerals is interested in the stability and safety of current mining operations as well as its future developments hence a full pit numerical analysis conducted in ABAQUS will provide the mining company with answers as to whether or not the future underground developments will affect the surrounding rock mass and more importantly, if there any potential failures.

2. Background

Xu [6] highlights how slope stability is one of, if not, the most important issues undertaken in mining engineering when designing an open pit mine. It is important to design a mine where the slope of the open pit is stable throughout the life of the mine. If there is a major failure of the slope it can cause a loss in production, but more importantly it may lead to workers being injured or even killed. The research discovered that slope stability could be analyzed using empirical methods however they do not give accurate results due to their experimental and semi-qualitative nature as shown by Read [7]. Geotechnical analysis of the open pit at Prominent Hill has been limited to static equilibrium, kinematic and probabilistic stability analysis. Where these methods have been successful in creating an adequate initial design, as the mining of the open pit progresses ever deeper and underground begins to excavate, geotechnical stability issues may arise that these methods are incapable of predicting. Limit equilibrium and probabilistic analysis methods are unable to be used to understand the influence of underground ore production on the overlying open pit nor the damage slopes experience as the open pit mine progresses. As described by Shen [8], limit equilibrium methods as well as empirical methods are limited to simplistic geotechnical problems as they encompass simple slope geometries and basic loading conditions and hence they cannot properly describe slope failure mechanisms in a complex pit shell geometry.

Numerical analysis has been identified as the most appropriate tool to investigate the influence of underground ore productions on the overall stability of the existing open pit. Thus this paper focuses on produced 3D full pit