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GEOTECHNICAL OPTIMISATION OF THE VENETIA OPEN PIT

ABSTRACT

Venetia Mine is situated south of the confluence of the Shashi and Limpopo rivers, 80 km West of Musina and 36 km North-east of Alldays in South Africa. Venetia is an open pit, truck and shovel operation which commenced full production in 1993. Mining began on the Cut 4 design in 2006 with a final planned open pit depth of approximately 500m below surface at a maximum waste stripping rate of approximately 50 million tonnes per annum.

The country rock assemblages at Venetia are part of the Limpopo Mobile Belt and mainly consist of metamorphic and intrusive igneous rocks. The stability of the pit is structurally controlled and the structure can be divided into two main components, ductile structure (foliation) and brittle structures (major structures and joints). A dominant metamorphic foliation cross cuts all the geology which results in an anisotropic rock mass strength. The interaction between the brittle jointing and foliation also locally impacts on bench stability and subsequent bench performance. The slope design is therefore highly dependent on the orientation of the pit slopes relative to structural features.

Up to 2009 Venetia mine employed high energy blasting techniques, mainly focused on achieving high production rates and optimum fragmentation, to develop the final walls of the pit. Excavating the highwalls with conventional production blasting techniques resulted in extremely poor highwall conditions. In 2009 this practice was ceased and the mine started experimenting with limit blasting techniques on the final pit limits. The benefit of the limit blasting was however not quantified. That same year a revision and optimisation of the business plan was undertaken of which one aspect was the review of the slope angles and design sectors. The acceptance criteria, as recommended by the Guidelines for Open Pit Slope Design (Read and Stacey, 2009) were used by De Beers to determine the acceptable level of risk for the optimisation programme.

Rigorous reviews of actual pit slope performance were conducted for the North and Southern slopes. This indicated that the bench performance in the Southern slopes can be isolated to distinct areas. The South-western portion of the slope had the highest incidence of complete bench failures (43%) followed by the Southern section (17%). See Figure 2.1. In turn rock

falls were prevalent in the North domain. This was aggravated by poor blasting resulting in the catch berms not being retained and thus not being effective at retaining rock falls. The mechanisms that initiated the variable bench performance and rock fall risk were not well understood at that stage.

The first Cut 4 slope stability design was conducted in 2008 and defined only two major domains [North: 56° stack angle, South: 40° stack angle] (Contreras, 2008). The South slope design assumed a slope striking parallel to the orientation of the foliation. The analysis indicated that steeper stack angles are achievable in the North domain however a lower slope angle was recommended due to the perceived rock fall risk and mining practices at the mine. The rock fall risk was however not quantified. Review of the data supplied by the operation to the consultant indicated that the orientation of the S2 foliation and joint populations were extrapolated from old exposures in Cut 2. In addition to the above no groundwater table was available for the first design in 2008.

Thus considering the improvement in mining practices, lack of understanding regarding the actual slope performance and extrapolated data that was used in the design the author deemed it appropriate to re-evaluate the Cut 4 design in 2009. The optimisation study was scoped by the author and consisted of various phases (1 – 3).

Phase 1 was aimed at providing initial input parameters into the strategic business plan (SBP) regarding slope angles (savings on waste stripping) (Strouth, 2009; Gomez, 2010) and bench heights (potential to increase productivity) (Contreras, 2010; Steffen and Terbrugge, 2009). The only new data for this phase was limited scan line mapping that was collected by the mine in the South-western quadrant of the pit and thus similar constraints relating to the orientation of the S2 foliation, joint sets and groundwater applied.

Phase 2 ran concurrently with the above work and was aimed at defining the orientation of the S2 foliation, joint data and pore pressures in the toe of the slope. This phase consisted of structural mapping, drilling, instrumentation installation; and modelling of the geology and ground water table by Basson (2011a) and Liu et al. (2011) respectively.

For the final phase of the optimisation (Phase 3) the Geotechnical domain model and slope design was updated using the results from Phase 2 of the study. The updated design incorporated the updated groundwater table and considered the orientation of the pit slopes relative to the foliation; and consisted of bench, inter-ramp and overall slope analyses.

Probabilistic limit equilibrium bench analyses were conducted by the author for every practical orientation of each domain, at various bench heights, using SWISA™ and PFISA™. For the inter-ramp and overall slope design limit equilibrium probabilistic analysis were conducted using the programme SLIDE™. The anisotropic strength model in SLIDE™ was used to account for the S2 foliation.

The bench and inter-ramp analyses indicated that steeper angles are viable in a number of domains. The stability of the pit walls in the Southern domains is mainly controlled by their orientation in relation to the major S2 foliation. In contrast the stack angle in the North domain is not controlled by the S2 foliation and/or rock mass strength. Here the interaction between brittle jointing controls the maximum catch berm and subsequent stack angle. The numerical finite difference code, FLAC™, was used to validate the results of the limit equilibrium stack analysis. The validation indicated that the limit equilibrium modelling is conservative when compared to numerical modelling and it is recommended that future studies use the response surface methodology by Chiwaye and Stacey (2010), whereby numerical modelling is used, to estimate the risk (probability of failure).

Strategies to monitor the quality of mining practices and related rock fall risk have also been developed and incorporated into the Code of Practice and related standard operating procedures for the operation.

The results of the optimisation project was included into the mine's strategic business plan in 2011 and resulted in significant financial savings.