

Integration of pitwall design into strategic open pit mine planning and the benefits of employing geotechnically optimal pitwall profiles for pit optimization

Demonstration through case studies of three metalliferous open pit mines

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Abstract

In open pit mining there is a clear trend of excavating mines of increasing depths, from less than 50 m deep in the 1920s to more than 1 km in recent years. Owing to the increased efficiency of mining equipment and improved exploration techniques and technology, the orebodies left to be exploited reach depths of even 2,000 m from the ground surface. The deeper a mine is, the higher the effect of pitwall steepness on the amount of waste rock excavated and, therefore, mine profitability. Hence, designing pit walls to be safe and at the same time as steep as feasible has never been more important. The steepness of mine pitwalls affects significantly not only mine profitability but also carbon footprint since mining operations are the primary responsible for carbon emissions.

Traditionally the design of pitwall inclinations is carried out by geotechnical teams with little interaction with mining engineers. Usually, the geotechnical engineer establishes the maximum inclination of any pitwall to be excavated within the various geotechnical domains of the mine. The design is performed following a prescribed Factor of Safety (FoS) or Probability of Failure, chosen based on the risk profile of the mining company. Then, the mining engineer, using various software packages (e.g. Datamine Studio NPVS, Geovia Whittle, Hexagon MinePlan, Maptek, etc.), computes pushbacks and the ultimate pit limit by performing a strategic pit optimization with the maximum acceptable pitwall inclination acting as a constraint. No further interaction occurs until the geotechnical team is asked to verify the stability of the final pitwalls produced by the pit optimization software. However, it is well known that the maximum inclination of a slope is a function not only of the prescribed FoS but also of slope height as well. Therefore, imposing a pitwall maximum inclination irrespective of the pitshell depth implies that the current design methodology gives rise to sub-optimal designs where often the pitwall inclination is either less (design overly conservative) or more (a below target FoS is adopted) steep of what could be.

To overcome the current limitations, participants will be introduced to a design methodology where pitwall inclinations are selected accounting for the pit depth and integrated into the strategic mine design (Utili *et al.*, 2022). This methodology is made possible by iterating between pit optimizer and geotechnical pitwall design (Figure 1). The improvements in financial returns that can be gained by adopting the proposed methodology will be showcased for three case studies of metalliferous mines: a copper mine in South America (Utili *et al.*, 2022), a gold mine owned by Kinross (Agosti *et al.*, 2021a) and the McLaughlin gold mine in California (Agosti *et al.*, 2021b). Also, in the current design practice, pit wall profiles are often designed to be planar in cross-section, especially within each rock layer with constant over depth inter-ramp angle. A new slope design software, OptimalSlope¹, can determine geotechnically optimal pitwall profiles of depth varying inclination for the design of each sector of the mine. OptimalSlope seeks the solution of a mathematical optimization problem where the overall steepness of the pitwall, from crest to toe, is maximized for an assigned lithology, rock properties, and FoS. The adoption of overall steeper profiles thanks to OptimalSlope leads to a further reduction in the amount of waste rock and, consequently, the stripping ratio. For each mine case study, both financial gains (in terms of NPV) and environmental gains (measuring the reduction in carbon footprint and energy consumption) are assessed.

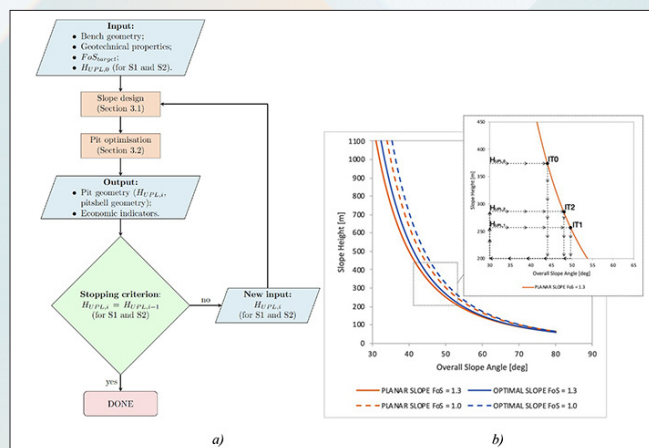


Figure 1 - Pit design process: a) flow chart illustrating the iterative process followed to determine the Ultimate Pit Limit (UPL) and pushbacks. Note that the process is the same irrespective of the shape of the adopted pitwall profiles. b) Slope (pitwall) height versus Overall Slope Angle for different FoS values and profile shapes (planar profiles in orange and optimal profiles in blue). Note the curves were derived for the specific geotechnical parameters of the case study mine. A different set of strength parameters would produce different curves, however the qualitative trend of the curves is valid irrespective of the rock strength values. After Utili *et al.*, (2022)

¹See www.optimalslope.com

Presenter's Biography



Stefano Utili is Professor of Geotechnical Engineering at Newcastle University (UK) and founder of OptimalSlope Ltd (<http://optimalslope.com/>). He is a Chartered Engineer and Fellow of the Institution of Civil Engineering. Prof. Utili is member of the International Technical Committee 208 "Slope stability in engineering practice" and has published extensively on the design of mine pitwalls.

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