

An overview of bench design for cut slopes with an example of an advanced dataset assessment technique

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Abstract

The empirical derivation of the minimum berm width and the formulae presented by the various design criteria are different due to the input parameters selected, thus resulting in a range of minimum berm widths that can be calculated for the same set of rock mass and geometric conditions.

When compiling a berm design model, in assigning a derived (calculated) friction angle and cohesion value, the Factor of Safety (FoS) and Probability of Failure (PoF) for a suite of kinematically identified plane or wedge sliding instabilities may be overestimated and may not be representative of true mining conditions.

Rather than applying dataset cutoff criteria to the FoS or PoF for plane or wedge instability spill volume, the use of all data regardless of the FoS or spill volume is required in order to accurately assess the minimum berm width that can be calculated and then recommended for the design. This is based on the assessment of all spill volumes, spill radii and the criteria accepted and applied.

As shear strength properties changeover the life-of-mine, so does the FoS. Assuming that the FoS is static and the derived PoF is indefinitely valid will result in a design that may be insufficient in maintaining the berm retention factor assigned.

Therefore, attaining and utilising derived FoS and PoF allows for all plane and wedge shape iterations compiled during the modelling process to be utilised. This methodology allows for the assessment of the minimum berm widths calculated using the published criteria and advanced dataset assessment techniques.

Keywords: bench design, shear strength parameters, berm retention factor

1 Introduction

Bench height and berm width contribute to the inter-ramp geometry on which an overall slope design is based. It is imperative to ensure that the inter-ramp geometry is empirically sound and that the design berm width is sufficient to maintain the berm retention factor required and therefore, the anticipated volume of failed material, should an instability occur. The berm retention factor, rock mass and geometric conditions of the discontinuities for the selected design sector inevitably define the berm width during the design process.

This berm retention factor is of paramount importance for the mitigation of rockfall, dependent on the percentage of the volume of material that exceeds the berm width.

Bench design analysis is usually conducted using published criteria such as the Ritchie Criterion (Ritchie 1963), the minimum berm width (Piteau & Martin 1977), the Modified Ritchie Criterion (Hustrulid et al. 2001), the minimum berm width using either conical or pyramidal spill radius (Gibson et al. 2006, adapted and applied by Rocscience) and the minimum berm width presented by Haines et al. (2006).

These criteria are either empirical or formula-based, and typically encompass varieties of input parameters such as the bench height, bench face angle, plunge of the intersection of the joints, the angle of repose, the volume of spill material and the bulk or swelling factor.

The likelihood of achieving a design is highly reliant on attaining the bench face angle with specific reference to the bench crest due to break back as well as frozen toes. Break back is controlled by the local geology and

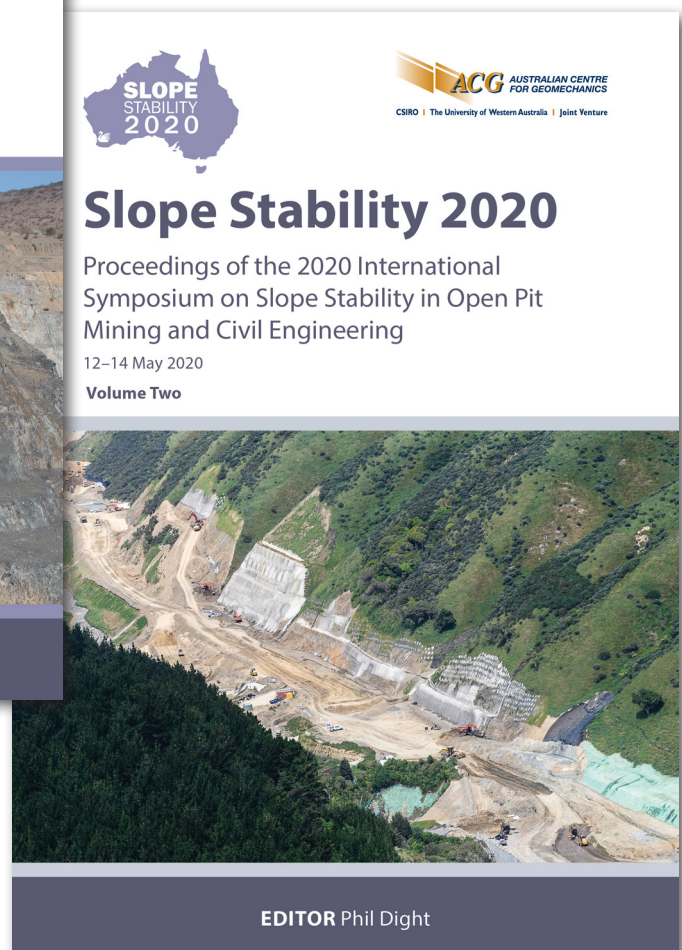
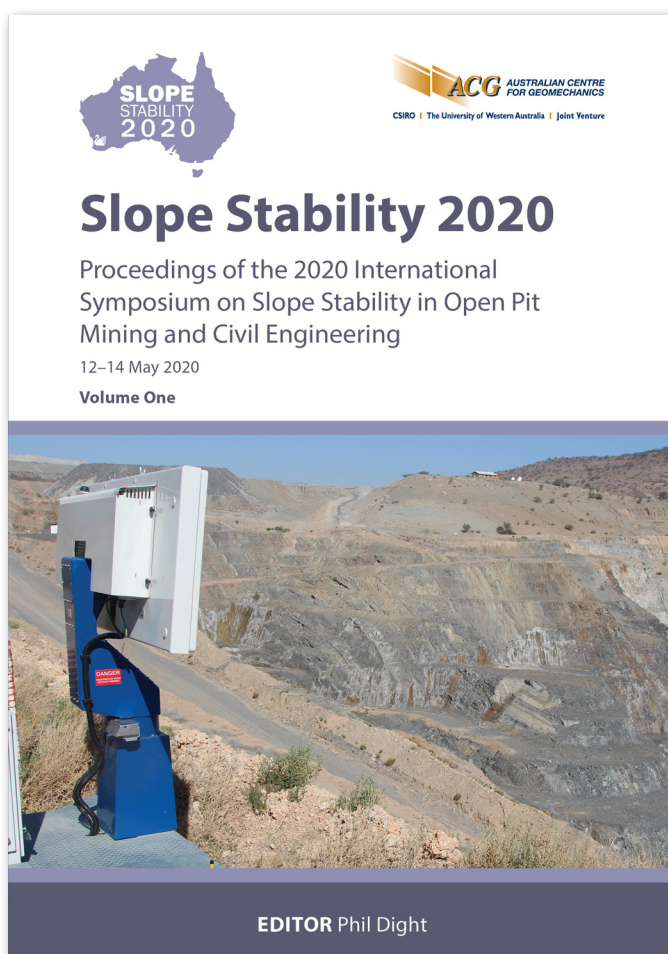
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References

- Abrahams, G 2015, *Bench-berm design: who really cares?*, SRK Consulting (South Africa) (Pty) Ltd, Cape Town.
- Carvalho, J ca. 2012, *Slope stability analysis for open pits*, Golder Associates Ltd, Mississauga.
- Coetsee, S 2014, 'An overview of bench design for cut slopes', *Proceedings of the 8th South African Young Geotechnical Engineers Conference*, The South African Institution of Civil Engineers, Stellenbosch, pp. 561–571.
- Gibson, WH, de Bruyn, IA & Walker, DJ 2006, 'Considerations in the optimisation of bench face angle and berm width geometries for open pit mines', *Proceedings of the International Symposium on Stability of Rock Slopes in Open Pit Mining and Civil Engineering*, The Southern African Institute of Mining and Metallurgy, Johannesburg, pp. 557–578.
- Gibson, W & Paul, J 2016, Comparison for estimating volume of failed wedges, SRK Consulting (Australasia) Pty Ltd, Perth.
- Grenon, M & Hadjigeorgiou, J 2010, 'Integrated structural stability analysis for preliminary open pit design', *International Journal of Rock Mechanics and Mining Sciences*, pp. 450–460.
- Grenon, M & Laflamme, AJ 2011, 'Inter-ramp and bench design of open pit mines: the Portage pit case study', *Canadian Geotechnical Journal*, pp. 1601–1615.
- Haines, A, Voulgaris, P, Walker, D & de Bruyn, I 2006, 'Geotechnical design considerations for the proposed Oyu Tolgoi open pits, Southern Mongolia', *Proceedings of the International Symposium on Stability of Rock Slopes in Open Pit Mining and Civil Engineering*, The Southern African Institute of Mining and Metallurgy, Johannesburg, pp. 133–154.
- Hafid Baroudi, D, Hantz, PD & Piguët, JP 1992, 'Bench stability in open pit mines: A methodology for jointed rock masses', *Regional Conference on Fractured and Jointed Rock Masses*, International Society for Rock Mechanics, Lisbon, pp. 67–72.
- Hoek, E & Bray, JW 1981, *Rock slope engineering*, The Institute of Mining and Metallurgy, London.
- Holley, K, Skayman, P & Zhiwei, H 2006, 'Geotechnical design for the open pits at Tanjianshan, China', *Proceedings of the International Symposium on Stability of Rock Slopes in Open Pit Mining and Civil Engineering*, The Southern African Institute of Mining and Metallurgy, Johannesburg, pp. 483–508.
- Hustrulid, WA, McCarter, MK & Van Zyl, DJA 2001, *Slope Stability in Surface Mining*, Society for Mining, Metallurgy, and Exploration, Englewood.
- Jermy, C, Kuppusamy, V, Fietze, CP & Hornsby, PK 2011, 'Open pit bench failure volume analysis and berm design – is it realistic?', *Proceedings of the International Symposium on Rock Slope Stability in Open Pit Mining and Civil Engineering*, Canadian Rock Mechanics Association, Vancouver.
- Martin, D & Piteau, DR 1977, 'Select berm width to contain local failures', *Engineering and Mining Journal*, vol. 178, no. 6, pp. 161–164.
- Miller, S 1983, 'Probabilistic analysis of bench stability for the use in designing open pit mines', *Proceedings of the 24th US Symposium on Rock Mechanics*, American Rock Mechanics Association, Alexandria, pp. 621–629.
- Miller, S, Girard, JM & McHugh, EL 2000, 'Computer modelling of catch benches to mitigate rockfall hazards in open pit mines', in J Girard, M Liebman, T Doe & C Breeds (eds), *Proceedings of the 4th North American Rock Mechanics Symposium*, AA Balkema, Boca Raton, pp. 539–535.
- Pierson, L, Davis, SA & Pfeiffer, TJ 1994, *The nature of rockfall as the basis for a new fallout area design criteria for 0.25: 1 slopes*, Oregon Department of Transportation, Salem.
- Piteau, D & Martin, DC 1977, 'Slope stability analysis and design based on probability techniques at Cassiar Mine', *CIM Bulletin*, vol. 70, no. 779, pp. 139–150.
- Read, J & Stacey, P 2009, *Guidelines for Open Pit Slope Design*, CSIRO Publishing, Collingwood.
- Ritchie, A 1963, *Evaluation of rockfall and its control*, Washington State Highway Commission, Washington.
- Rocscience n.d. a, *Bench Design in Rocplane Tutorial*, Rocscience, Toronto.
- Rocscience n.d. b, *Bench Design in SWedge Tutorial*, Rocscience, Toronto.
- Whyatt, J, McLaughlin, M & Miller, S 2004, 'Analysis of bench crest performance at the Yellowstone Mine', in M McLaughlin & R McNearny (eds), *Proceedings of the 39th Symposium on Engineering Geology and Geotechnical Engineering: Research to Practice*, Montana Tech, Butte, pp. 149–163.
- Whyatt, J, Miller, S & Dwyer, JG 2004, *NIOSH computer programs for bench crest failure analysis in fractured rock*, The National Institute for Occupational Health and Safety, Cincinnati, <https://www.cdc.gov/niosh/mining/UserFiles/works/pdfs/ncpfb.pdf>