Estimation of shear strength of very coarse mine waste

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Abstract

Evaluating the shear strength of mine waste rock containing particles of metric scale is challenging because commercial laboratory testing devices can only accommodate samples composed of particles a few centimetres in size. The shear strength empirical model of Barton & Kjærnsli (1981) is therefore frequently used to assess the non-linear shear strength of very coarse granular material for stability assessment of very high mine waste dumps. In this article, we discuss practical methods for collecting the information required as input to the model, and we also illustrate the implementation of deterministic and probabilistic approaches for estimating the shear strength of several waste materials from a banded iron formation located in the Pilbara region of Western Australia.

Keywords: shear strength, very coarse granular material, mine waste dumps

1 Introduction

Evaluating the shear strength of mine waste rock containing particles of metric scale is challenging because commercial laboratory testing devices can only accommodate samples composed of particles a few centimetres in size. To overcome testing limitations, the shear strength is frequently estimated using the shear strength empirical model of Barton & Kjærnsli (1981) (B–K criterion), which considers the nonlinearity of the shear strength envelope, characterising the behaviour of very coarse granular materials submitted to very high loads (Leps 1970; Ovalle et al. 2020).

In the B–K criterion, a stress-dependent structural component of the shear strength is parametrised with the equivalent roughness ($R$) and equivalent strength ($S$). The structural component is added to the basic friction angle ($\phi_b$) of the parental rock to determine the shear strength of the waste rock material. Barton modelled this criterion using $R$ and $S$ as equivalent to his joint roughness coefficient and joint wall compression strength in his shear strength criterion for rock joints (Barton 1973) (i.e. asperity and particle contact in common). In this paper, different methods are discussed to gather the information required for the practical implementation of the B–K model, and deterministic and probabilistic approaches are presented for the shear strength determination of coarse waste for waste dump design. The approaches are illustrated using the information gathered for a project where the waste rock materials originated during mining activities from a banded iron formation in the Pilbara region of Western Australia.

2 Strength model for coarse granular materials

The B–K empirical non-linear model is represented by Equation 1. The model is intended to be utilised for characterising coarse materials like rockfill and blasted rocks, which typically undergo crushing under the imposed loads and therefore exhibit a non-linear shear strength envelope. In the B–K model, the effective friction angle of the waste rock is estimated by adding to the basic angle of friction ($\phi_b$) a structural component of strength (which is stress-dependent), determined by the degree of roundness of the particles and the porosity of the arrangement of particles. According to the expression, the friction angle is at least equal to the basic friction angle and varies in a magnitude $R$ for a 10-fold increase of $S/\sigma_n$.

$$\Phi' = \phi_b + R \log_{10} \left( S/\sigma_n \right)$$

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6 Summary and conclusion

The methodology to characterise the shear strength of coarse waste materials using the B–K model was described and illustrated with data from seven waste materials from the banded iron formation in the Pilbara region of Western Australia. The definition of the input parameters of the model using the results of laboratory testing, field determinations and judgement was described, and the evaluation of the shear strength represented by the friction angle was carried out using deterministic and probabilistic approaches.

The deterministic approach is based on using conservative values (25th percentile) of the input parameters, whereas the probabilistic approach uses probability distributions to represent them and a MC analysis to define the distribution of $\phi$. In both cases, the objective was to account for the uncertainty in the properties of the waste material. The comparison of the deterministic results with the 75% confidence values from the probabilistic analysis indicates that the former are in general more conservative. This is because the probabilistic analysis takes into account the structure of the datasets and considers the propagation of the uncertainty of the parameters through the calculation process. The results of the probabilistic analysis presented in the paper correspond to the 75% confidence values, however, the level of confidence for a particular application needs to be selected so that it is consistent with the criterion of acceptability for the slope stability analysis. The use of the probabilistic results for design was examined and the selection of the appropriate values of friction angle for design considering spatial variability aspects of waste dumps was discussed.

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References


