Abstract

The stability of overburden dumps is crucial for efficient surface mining operations. The shear strength of dump materials is generally defined in terms of cohesion and the angle of internal friction. These parameters are primarily affected by particle size, particle packing, dry density, and moisture content. The traditional laboratory tests do not consider the variability of these factors that may exist in an in situ dump. The assessment of the soil-rock mixtures (S-RM) deep inside a slope bench is a challenging task, as these materials are inaccessible from the bench. Hence, the global objective of the thesis is to evaluate the physical properties and mechanical behaviour of the in situ dump materials through a combination of efficient laboratory and field investigations.

The particle size distribution estimated in laboratories does not consider coarser particles, mostly because of sieve size constraints and the unavailability of large testing boxes. In this study, a deep learning-based model was developed to predict in situ particle size distribution from dump images. Two convolutional neural network (CNN)-based models, namely Mask R-CNN and CenterMask, were trained on a dump image dataset generated by manually annotating approximately 45,000 particles from 300 images. A web-based application was developed for segmenting particles up to a size of 5 mm in real-time and also to generate particle size distribution curves.

In order to understand the effects of particle size, particle packing, dry density, and moisture content, laboratory-scaled direct shear tests were conducted on reconstituted dump samples. The stress-displacement curves of these tests were interpreted along a vertical section of the dump resembling the upper and lower benches of a 70 m to 90 m height dump. It was revealed that the cohesion decreases, and the angle of internal friction increases with an increase in particle size ranges. Both of these parameters would also increase with an increase in dry densities due to age and compaction.

An analytical relationship was also derived to estimate in situ porosities along a vertical section of the dump slope. The porosity-height relationship aimed to extend the laboratory investigations to field conditions. It was observed that the void ratio (determined from this relationship), being a unique property, can be employed to forecast the in situ shear strength of the dump.

The integrated results from the laboratory and field investigations and the CNN-based model were compiled to generate a shear strength dataset for the dump. The Gaussian Process Regression (GPR)-based model was then trained on this dataset and employed to forecast the in situ cohesion and angle of internal friction of the dumps for any image of the dump surface at a known height.

Keywords: overburden dump, in situ shear strength, particle packing, density, porosity, deep learning, probabilistic machine learning