SYSTEMATIC APPROACH TO INTEGRATED MINE BENCH OPTIMIZATION IN SOIL AND ROCK OF SRI LANKAN OPEN PIT MINES – A CASE STUDY

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Degree of Master of Engineering

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Thesis submitted in partial fulfillment of the requirements for the
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DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person expect where the acknowledgment is made in text.

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The above candidate has carried out research for the Master's thesis under my supervision.

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Professor U.G.A. Puswewala Date

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ABSTRACT

Instabilities and failures in rock slopes occur due to numerous factors such as unfavorable slope geometries, geological discontinuities, weak or weathered materials in the slopes, existing weather conditions and environmentally induced external factors such as heavy precipitation, seismic activities and groundwater. Bench optimization is carried out to maintain bench height and dip of the slope within an allowable factor of safety, thus avoiding rock slope failures and instabilities. Therefore, optimum determination of these geometrical features has become a most significant part of soil and rock slope stability analysis in Open Pit Mining where multiple benches of excavation are maintained.

Field work related to this research study primarily comprised of observation of structural geological features (dip and strike) and other measurements and observations (joint spacing, separation, condition of joint) required for analysis work, including Slope Mass Rating analysis, at the selected site of Halbarawa, Sri Lanka. Furthermore, soil and rock samples were collected from the selected site to perform laboratory tests. Proctor compaction test and direct shear test were carried out for selected samples to evaluate the overburden slope stability. Simultaneously, stability of soil and highly weathered rock slope was analyzed by SLOPE W software. In order to analyze rock slopes, initially possible rock failure modes were identified using Georient software. If it indicated some tendency to fail, a detailed analysis of wedge failure was carried out using GEO5 software. Further, Toppling and Planer modes of failure were analyzed via SMR analysis.

The study focused on optimizing the bench geometry of mine slopes necessarily consisting soil, highly weathered rock and fractured rock in order to explore ways for safe and economical bench designing. This was achieved by integrating kinematic, empirical and limit equilibrium approaches for slope stability investigation and guidelines were finally developed so that the same methodology can be universally applied for assessing the soil and rock slope stability in similar situations. This procedure was developed through the case study of Halbarawa Mine.

Results indicated that the stability is more sensitive to variation in cohesion than variation in friction angle of overburden profile. As far as the bench geometry is considered, multiple benches are seen as the most reliable mining methods for steeply dipping benches. According to RQD of each location, the rocks in the particular area varied from moderately hard rocks to hard rock. The Kinematic analysis disclosed that most of joint planes intersect with each other and produce various potential failure mechanisms. The dip and the dip direction of the slope faces determine the possibility of failure and the mode of failure with respect to the discontinuity plane.

For the Halbarawa site, as per the SMR analysis, face 1, 2 and 3 can be categorized into completely unstable (V), partially stable (III) and unstable (IV) rock stability classes respectively. It was also understood that surcharge load is a more critical factor than the static water pressure when a wedge failure is considered. The most successful, economical and rapid remedial measures to enhance the stability of rock slope are reduction of bench height and reduction of bench angle.

KEYWORDS: Bench optimization, Open Pit Mines, SMR, surcharge load, stability classes, Kinematic analysis.

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ABBREVIATIONS

D/D	– Dip Direction
GSI	– Geological Strength Index
HWR	– Highly Weathered Rock
Jn	– Number of joint sets
Jv	– Volumetric Joint Count
M-B	– Multiple bench orientation with slip circle exit through HWR
M-T	– Multiple bench orientation with slip circle exit through top soil
P	– Planer failure
RMi	– Rock Mass Index
RMR	– Rock Mass Rating
RQD	– Rock Quality Designation
S	– Joint Spacing
S-B	– Single bench orientation with slip circle exit through HWR
SMR	– Slope Mass Rating
S-T	– Single bench orientation with slip circle exit through top soil
T	– Toppling failure
UCS	– Unconfined Compressive Strength
W	– Wedge failure
σ_{cm}	– Unconfined Compressive Strength of rock mass