INFLUENCE OF BENCH GEOMETRIES ON ROCKFALL BEHAVIOUR IN OPEN PIT MINES

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A research report submitted to the Faculty of Engineering, University of the Witwatersrand, Johannesburg, in fulfilment of the requirements for the degree of Master of Science in Engineering.

Johannesburg, 2005

DECLARATION

I declare that this project report is my own, unaided work. It is being submitted for the Degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

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F B Musakale

__________day of___________________ ______

ABSTRACT

Rockfalls are a significant risk in open pit mines. Once movement of a rock perched on the top of a slope (bench) has been initiated, the most important factor controlling its fall trajectory is the geometry of the slope (bench). The best possible knowledge of rockfall trajectories and energies is important in order to determine accurate risk zoning and for the design and construction of adequate defence systems near the threatened areas.

This study attempts to determine the influence of bench geometries, and the coefficient of restitution of rock, on rockfall behaviour. A study of literature was carried out to review previous studies and other relevant information on rockfalls and their analysis. The literature may be divided into two categories: experimental methods involving physical modelling, and computer models involving rockfall analyses using computers analysis methods. Rockfall computer simulation is considered to be applicable, quick to carry out and reproducible. The accuracy of the results depends on the knowledge of site conditions and slope geometry. The use of the Modified Ritchie criterion for the design of catch benches in open pit mines was also investigated.

The assessment of bounce height, maximum run-out distance and kinetic energy achieved during the fall of rocks on the catch bench were the bases of the evaluation of the results obtained in this project. The computer program, Rocfall Version 4, was used for the purposes of the research. The following parameter variables were considered in the analyses: three types of rock; slopes with three stack configurations; four bench heights; and four bench face angles.

The results show that, for all stack configurations and rock types, the maximum run-out distance and maximum bounce height increase as functions of bench height at a specific bench face angle. A single bench configuration provides a maximum run-out distance of falling rocks larger than the value determined using the Modified Ritchie criterion for all rock types and bench face angles. Multiple bench stack configurations provide maximum run-out distances less than the value determined using the Modified Ritchie criterion only for the 90^o bench face angle in all rock types; those with 60^o, 70^o and 80^o bench face angle provide a larger maximum run-out distance. Therefore, the validity of the Modified Ritchie criterion for the design of catch bench widths in open pit mines with inclined benches must be questioned.

According to Ritchie's study (1963), rocks that fall in trajectory (free fall) seldom give high bounces after impact on a catch bench. This project shows that this finding is valid for rocks with low coefficients of normal restitution. Rocks with lower coefficients of normal restitution provide larger run-out distances with flatter bench face angles compared with rocks with higher coefficients. In contrast, rocks with higher coefficients provide larger run-out distances than those with lower coefficients for steeper angles.

The consideration of the influence of geometry (shape) of falling rocks on rockfall behaviour showed that, for a flatter slope, as could logically be expected, the maximum run-out distance is greatest for rounder rocks and smallest for flatter slabby

rocks. This is due to the fact that on a flatter slope, the mode of falling of rounder rocks is rolling down the slope. This mode provides essentially no resistance to motion, resulting in largest maximum run-out distance. In contrast, for long flat slabs, the mode of movement will be sliding, which results in a smaller maximum run-out distance. The maximum run-out distance as function of rock shape reduces as the normal coefficient of restitution increases.

For all rock types, the maximum bounce height reduces as a function of the friction angle for flatter slopes. This is due to the fact that rocks are in contact with the slope during the rockfall. As the coefficient of normal restitution increases, an increase in the maximum bounce height results.

ACKNOWLEDGEMENTS

The research described in this dissertation was part funded by the Centennial Trust.

I am grateful to Prof T.R. Stacey, my supervisor, for giving me this opportunity to work on this project and for his patient guidance and encouragement throughout this work.

I would like to thank the academic staff of School of Mining Engineering at the University of the Witwatersrand for valuable knowledge I received from them.

I wish also to thank my family, for their spiritual and moral support from Democratic Republic of Congo.

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LIST OF SYMBOLS

a	Long axis of ellipsoidal body
b	Short axis of ellipsoidal body
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D	Rock catchment area depth (m)
E_p	Potential energy (J)
g	Gravitational accelaration (m/s^2)
h	Height of bench (m)
H	Unit vertical distance of a catchment area slope
Hz	Hertz
i/s	Rotational velocity of a falling rock
m	Mass of falling rock (kg)
n	Positive integer
θ	Bench face angle (^{o})
RX	Type of catch fence
RN	Coefficient of normal restitution
RT	Coefficient of tangential restitution
tm/s	Momentum
tm^2/s	Angular momentum
V	Unit horizontal distance of a catchment area slope
W	Ditch width (m)
x	x-coordinate

LIST OF ABBREVIATIONS

CD-R	Compact disk recorder
deg	Degree
Inc.	Incorporation