ARTICLE IN PRESS

International Journal of Mining Science and Technology xxx (2016) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Mining Science and Technology

journal homepage: www.elsevier.com/locate/ijmst

Optimization of the catch bench design using a genetic algorithm

Ruvin Wijesinghe Dakshith, You Greg *

Mining Engineering Program, Faculty of Science and Technology, Federation University Australia, Ballarat 3350, Australia

ARTICLE INFO

Article history:
Received 18 May 2015
Received in revised form 26 August 2015
Accepted 13 November 2015
Available online xxxx

Keywords:
Catch bench width
RocFall
Genetic algorithm
Simulation-Optimization model

ABSTRACT

Rockfalls are one of the hazards that may be associated with open pit mining. The majority of rockfalls occur due to the existing conditions of slopes, such as back break, fractures and joints. Constructing a berm on the catch bench is a popular method for the mitigation of rockfall hazards in open pit mining. The width of the catch bench and the height of the berm play a major role in the open pit bench design. However, there is no systematic method currently available to optimize the size of these parameters. This study proposes a novel methodology which calculates the optimum catch bench width by integrating the rockfall simulation model and genetic algorithm into a Simulation-Optimization Model. The proposed methodology is useful when used to determine the minimum catch bench width, or the maximum overall slope angle, insuring that a sufficient factor of safety of the slope is included while maximizing the overall profitability of the open pit mine.

1. Introduction

Rockfall is one of the major hazards that may occur in open pit mining potentially causing damage to equipment and humans. Depending on the magnitude of the mass movement in the rockfall, these events are also defined as rockslides or rock avalanches [1]. Since this is a natural hazard, it has been a challenge for the engineers to develop preventive measures against rockfalls. Some of the currently used preventive methods include the construction of catch or barrier fences, restraining nets and developing embankments [2–4]. This study focuses on the catch bench development which is currently the most widely used rockfall prevention methodology in open pit slope design.

A catch bench is a bench designed to retain the falling rock fragments when a rockfall occurs. The improper design of catch benches can affect the overall safety of the mine in two different ways. Firstly, if the rock detaches from the topmost benches, the required holding capacity of the catch bench may be insufficient and therefore the material may not be retained on the bench. Secondly, if the rock fragment falls to the bench below the catch bench, it can again reduce the capacity of the bench to hold the material and this can trigger more rockfall. Therefore, catch bench width is one of the important considerations when designing bench geometry. To improve the functionality of the catch bench, a berm is added at the edge of the bench, to increase the retaining capacity of the catch bench. Moreover, the berm can provide safety for mining vehicles used in the clearance of fallen rock fragments. The design of the berm is an important part when planning an open pit slope. If the berm is too high it leads to high construction costs. Furthermore, with the increase of the berm height, its width increases, reducing the available space for vehicle movement on the bench.

The rockfalls can be categorized into four major motion types. They are free fall under gravity, bouncing, rolling and sliding. Bouncing is the most complex motion type. However, bouncing motion can be simplified using the restitution coefficient. Rolling and sliding are controlled by the friction angle of the slope surface and falling rock [5]. In the free fall under gravity, rocks travel through the air and the air friction acting on the rock is considered to be negligible. The simulation models used for the rockfall analysis should incorporate all four motion types [6]. Studying these motion types requires a specific set of parameters that affect the trajectories. Majority of the simulation models are designed as lump mass models, while some other models use the rigid body models. The simulation model used in this study, "RocFall", is based on a lumped mass model.

The travelling distance of the rock in a rockfall can be highly varied depending on the geology and slope geometry of the area. Therefore, this creates a need to change the catch bench width accordingly to catch the rock created by a rockfall. Several attempts were conducted previously by researchers who identified methodologies to minimize the catch bench width [5,7,8]. These studies were conducted by either simple estimate approaches or complex reliability based methods. Most studies were conducted by empirical methods for a single slope even though an open pit

* Corresponding author. Tel.: +61 3 53279136.
E-mail address: g.you@federation.edu.au (G. You).

http://dx.doi.org/10.1016/j.ijmst.2016.09.008
2095-2686/© 2016 Published by Elsevier B.V. on behalf of China University of Mining & Technology.

mine is a complex system with a number of slopes [9–11]. Therefore, there is a lack of research into the optimization of the catch bench design in open pit mines. This study suggests a novel method which uses the parameters coefficient of restitution, friction angle and slope geometry along with the genetic algorithm, to optimize the catch bench design.

2. Methodology

The methodology used for the optimization of catch bench designs can be described in four steps as follows.

2.1. Identification of parameters affecting the travelling distance of the falling rock

Extensive literature review was conducted to identify the major parameters which affect the travelling distance of falling rock. Bench height, bench angle, weight of falling rock, the number of benches, friction angle, velocity of rock release and material coefficient of restitution are the generic parameters that affects a rockfall. However, the aim of this research was to optimize the bench width according to the geological parameters. Therefore, a sensitivity analysis was conducted to identify the most influential geological parameters. Fig. 1 represents the sensitivity analyses of the geological parameters. The input data for the sensitivity analyses are listed in Table 1.

Coefficient of normal restitution (*Rn*) and coefficient of tangential restitution (*Rt*) values vary from 0.1 to 0.8 as shown in Fig. 2 and the sensitivity of the all the geological parameters were analyzed. From the sensitivity analysis it is evident that most influential parameters for the rockfall are *Rn*, *Rt* and the friction angle. Fig. 3 shows the sensitivity analyses of the geometric parameters. It can be concluded that the geometric parameters are equally important as geological parameters on the travelling distance of the rockfall.

Furthermore, geology in the same area may not be uniform and have slight variations. These slight variations can affect the *Rn* and *Rt* values. To address this, the average standard deviation of *Rn* and *Rt* for the area was calculated. The literature reports the majority of standard deviation values for *Rn* and *Rt* are between 0 and 0.15 [12]. Therefore, 0.15 was chosen as a reference representing the maximum standard deviation value.

2.2. Problem formulation

The existing methods which calculate the minimum bench width are normally empirical methods. One of the disadvantages with empirical methods is that it does not account for the variation in geological parameters in different regions. Most of the empirical methods are used to obtain the width of a single catch bench [5]. In this study a mathematical optimization method is described to address this. The aim of this study was to minimize the catch bench width within the constraints of the rock retention percentage. The mathematical formulation can be represented as follows:

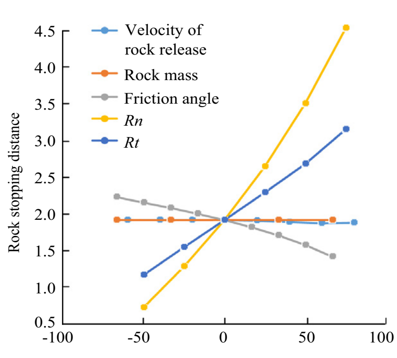

Fig. 1. Sensitivity analysis of geological parameters.

Table 1
Input data for sensitivity analyses.

Selections	Parameter	Value
Geological parameter selection	Velocity of rock release (m/s)	0.5
	Weight of falling rock (kg)	15
	Friction angle (°)	30
	Coefficient of normal restitution (*Rn*)	0.4
	Coefficient of tangential restitution (*Rt*)	0.4
Geometric parameter selection	Bench number	1
	Bench height (m)	12
	Bench angle (°)	70
	Rock type	Clean hard bedrock *Rn*: 0.53,*Rt*: 0.99, friction angle: 30°

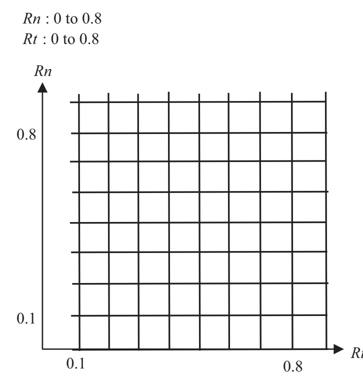

Fig. 2. *Rn* and *Rt* grid.

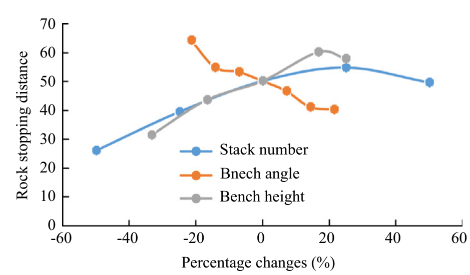

Fig. 3. Sensitivity analysis of geometric parameters.

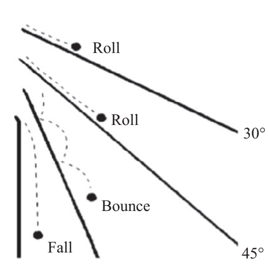

Fig. 4. Generalmode of motion of rocks [9].

Please cite this article in press as: Ruvin Wijesinghe D, You G. Optimization of the catch bench design using a genetic algorithm. Int J Min Sci Technol (2016), http://dx.doi.org/10.1016/j.ijmst.2016.09.008