International Journal of Civil and Structural Engineering– IJCSE
Volume 3 : Issue 1 [ISSN : 2372-3971]
Publication Date: 18 April, 2016

Simulating and Mitigating of Rockfall Hazards in Amstetten District, Austria

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Abstract - This paper presents the results and analysis of a 2-D rockfall simulation program by simulating rockfall trajectories on a longitudinal profile of the slope located in the District of Amstetten, Austria. The results show that the kinetic energy of the simulated rockfall threat the settlements located at the slope toe area. Rockfall barriers construction is in need to be installed to reduce the rockfall impacts.

Keywords: simulation, mitigation, rockfall, slopes, hazards, barriers

I. Introduction

Various rockfall cases have been reported to the Austrian Service for Torrent and Avalanche Control (ASTAC). Three major rockfall cases have been investigated since 2011 in the Amstetten Districts, Austria.

The Amstetten district is geographically located at the central part of Austria, has an area of 52.22 km ², its population in 2014 was about 28 thousand people [5]. At least three cases have been reported to pose rockfall hazards threatening houses and roadway infrastructures within this area [15].

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As example resident houses in Waidhofen/Y, Weyrer Straße, Amstetten was stricken by rockfall (D>50 cm) in mid-2011 (Figure 4) and a road way B121 connecting Waidhofen and Gaflenz was also under threat of the rockfall hazards as some rock blocks have passed through railways. However there were no major accidents reported.

Figure 1. Location of Amstetten district, Austria

This paper demonstrates three major steps for the assessment of the rockfall hazards, there are; (i) calculating of rockfall relative risk, (ii) simulation of rockfall run-out, and (iii) development of rockfall barrier model.

Based on the existing condition at the field, the blocks of rockfall sizes were classified into 4 groups; Group 1 = < 0.01 m^3, Group 2 = 0.01 - 0.2 m^3, Group3 = 0.2-0.4 m^3, Group 4 = 0.4-0.6 m^3.

Figure 2. Four different block sizes of the rockfall.

Based on the field survey data, encompassing 20 rockfall blocks gathered on the slope toe at the Amstetten, it was calculated that 53% of the size of the rock blocks falling at the Amstetten Slope was about 0.03-0.10 m^3 and, 21% of the size was less than 0.02 m^3.

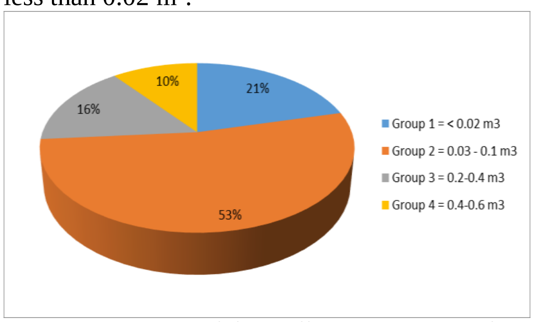

Figure 3. Percentage of four different block sizes of the rockfall

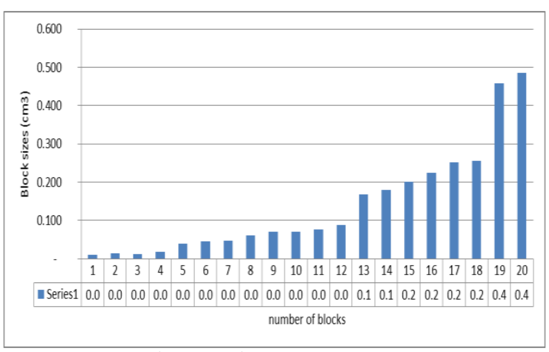

Figure 4. Types of the rockfall blocks.

Hence, based on this historical data, it is projected that the highest probability of rock blocks may fall from this slope was at the size of less than 0.10 m^3 (26 kg per rock block).

II. Calculating of Risk Hazards

The slope profiles located at the Amstteten District was investigated. This slope profiles are located close to habitant areas and not far away from the railway Waidhofen/Y track (10-20 meter from the slope toe). Some blocks of rockfall (with the size of 60x40x50 cm) crushed a house located at the slope toe, and others were stopped at the house fences in 2011.

In order to identification of relative rockfall risks, it is required to manage risk simulation process [7] and [8].

Rockfall Simulation

This process is to simulate the rockfall trajectories and to calculate kinetic energy of the falling blocks using the Rockfall software application, provided by the Institute for Geotechnics, Vienna University of Technology, Austria. The main input parameters are as follow: (i) slope geometry including its height (m), (ii) gradient (degree), (iii) slope surface, (iv) block-size distribution on the slope, (v) number of blocks present, (vi) type of surface, and surface roughness (has no dimension as it is m/m), and (vii) rockfall bouncing heights derived from hit-scars on the trees (m).

Input Data

Based on the field survey it was revealed that, the Amstetten slope has a vertical height of 132 m, with one small hiking trail crossing in the middle-slope. There are 3 houses located at the slope toe. It was also identified that the rockfall bounching height was 50 cm to 180 cm longitudinal land surface. These values were then used to calibrate the results obtained from the rockfall simulation.

The parameters of dynamic friction angle (Rg) was set at 20-30 degree, and static friction angle (Rh) was set at 30-45 degree. References [2] and [4] recommended values of Rh (static friction angle) < 45 degree.

Dn (normal damping) was 0.03-0.07, Dt (tangential damping) was 0.70-0.96, Rw (rolling resistance) was 0.02-0.70 (based on Refernce 4, it is recommended to use Rw value < 0.85) [4].

Surface roughness (Oa per Of) was estimated to 0.25m/1m to 0.5m/1m. A deviation of 10% around was allocated to all parameters values above.

Simulations

Based on a computer simulation, using iteration for 1000 falling blocks, @ 0.1 m^3 per block (plus minus 10%), with the rock mass of 2.60 tons/m^3, it was revealed that the kinetic energy of rockfall at the average of 35.73 kJ (at 150 m from the absys of the slope profile (Figures 5 and 8)

The average of rock blocks bouncing height was 64 cm from the ground surface (Figure 5).

Figure 5. Profile of Slope geometry with a single rockfall simulation.

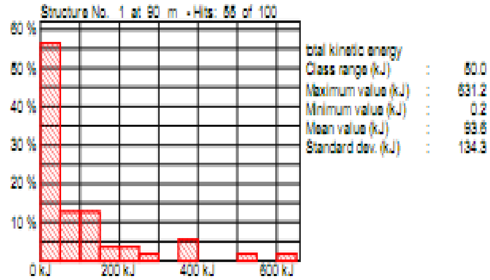

Figure 6. Kinetic energy of the rockfall.

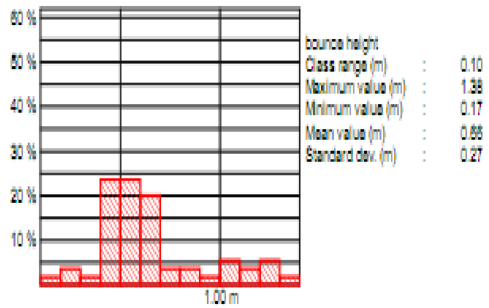

Figure 7. Bounching heigth of the rockfall.

For this case (with a block size of 0.1m^3), the higher the roughness of the slope terrain, the higher the kinetic energy and bounce height will be. These results are consistent with the results from Matjaˇz Mikoˇs, Urˇska Petje, and Mihael Ribiˇciˇ, 2006 [9].

As the size of the rock block is relatively small (0.1 m^3 per block) this reseach found that an "egg box effect" has been occured.

The smaller the block size passing a rough slope terrain, the lower the kinetic energy will be produced. Then most of rockfall stationary before reaching the slope toe.

As long as the size of the block is smaller than the range of slope roughness (Oa per of), the block will have a higher chance to reach a standstill position along the slope [2]. Approximately 16% of rockfall stationary before reaching the slope toe.

This research also simulate bigger rock block size (for example 0.5 m^3, as there is a 10% of the size of rockfall was 0.5 m^3) the higher it kinetic energy will be. This study found that the maximum kinetic energy of rockfall involving a block-size of 0.5 m^3 was at the average of 380 kJ). Bouncing height of the rockfall was < 2 meters (at the logintudinal diriction from the slope surface).

Based on the field investigation and simulation, these results were then used to design rockfall barriers.

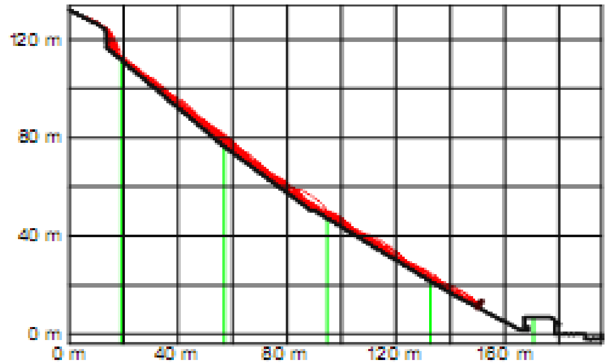

Figure 8. Simulation of rockfall trajectory along the slope surface.

The disign criteria can be seen from thefollowing table.

Table 2. Criteria of slope conditions

No.	Criteria	Value
1	kinetic energy maximum (kJ)	380.97
2	Kinetic energy mean (kJ)	35.73
3	Bounce height maximum (m)	1.75
4	Bounce height mean (m)	0.64
5	Barrier height (m)	2.00
6	Percentage hits (%)	84
7	Mass max (ton)	1.81
8	Mass mean (ton)	1.11

Thus, it is recomended to construct concrete wall barrier (capable to restrain up to 500 kJ kinetic energy of rockfall > maximum kinetic energy 380 kJ) (figure 8). The height of barrier is 2,00 m. Approximatelly 84% of rockfall blocks may hits the barrier with an average kinetic energy of 35.73 kJ.

Figure 7.Concrete wall barrier.

The posisition of the concrete barrier was suggested at 150 m from the logitudinal absyse coordinate of the slope (figure 5).

Conclusion

A 2-dimension of Rockfall 6.1 computer program used to simulate the slope at Amstetten has satisfied the research objectives. The results found that a kinetic energy of rockfall may reach 380 kJ (2% of blocks), with the maximum of bounce height was 1.75 m, and the probability of the rock blocks may hit the house(s) and reach the slope toe was 87.9%. Thus, it is recommeded that to construct concrete retaining wall with height of 2 m, with the distance of 150 from the slope longitudinal direction.

Acknowledgments

Research Funding has been provided by the Directorate General of Higher Education of the Republic Indonesia in the form of Program of Academic Recharging (PAR) 2011. The Authors whishes special thanks to the Institute for Geotechnics, Vienna University of Technology, Austria, Engineering Faculty, University of Riau, Indonesia, and the Austrian Service for Torrent and Avalanche Control, for their engagement assisting us in accommodating research facility and organizing site investigation, and advices

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