NUMERICAL SIMULATION APPROACH TO EVALUATING ROCKFALL STABILITY USING VIBRATION RESPONSE MONITORING

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1. INTRODUCTION

Rock falls is described as the downward movement of the detached rock block from a slope of a cliff (Cruden & Varnes, 1996). The fall is characterized by either freefall, bouncing, toppling or sliding of rocks. The occurrence of rock fall is a major concern in mines and road highways even though they pose less damage than the bench, stack and slope failure. Unlike other failures, rock falls are considered not to have precursors thus unpredictable and this factor shifted the focus of most researches to the mitigations of rock falls than detection based on the occurrence of frequencies and observations from specification locations. Prediction of a failure normally requires a precursor for instance in stack failures, change in parameters such as displacement and velocity can be used to detect the movement before the failure and this highly depends on the time taken to collapse. Advances in failure prediction in the past 2 decades have become more reliable and widely used, as more remote sensing and contact techniques are developed which include RADARs, GeoMos and inclinometers (Famsden, et al., 2015), just to mention a few. However to detect rockfalls is still a challenge due to its nature of instantaneous time of collapse and no warning signs such as a gradual change in displacement. Recently Saito, et al., 2011 carried out an empirical simulation in the lab illustrated by Fig. 1 and in the field to investigate the vibration characteristics of rock blocks as precursors. They came up with a relationship between vibration signatures and stability. Since there is an empirical relationship, a numerical model was developed to relate vibration characteristics to the stability of rock blocks. In the simulation process, rock block models were hit by simple sine wave to comprehend the effects of the mechanical stability of vibration characteristics. Results were then compared with findings from empirical experiments.

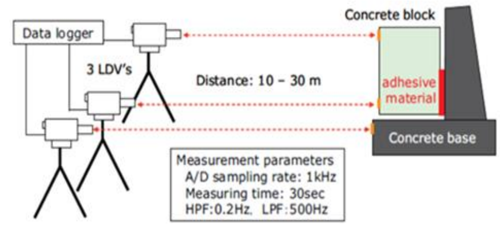

Figure 1 Schematic diagram of the measuring system in the lab (Saito, et al., 2011)

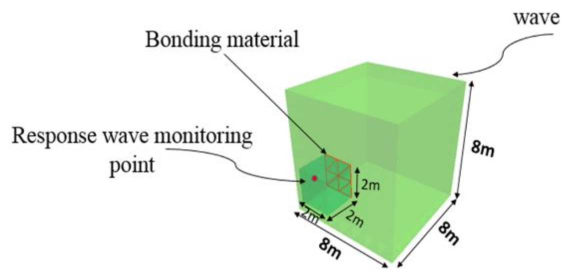

Figure 2 Setup model for numerical analysis.

Table 1 Properties of the bonding material used for the simulation.

Property	Case1	Case 2	Case 3
Bonding length	0.5m	1m	1.5m
Strength	low	medium	high

2. SIMULATION OUTLINE

A numerical program Flac3D was used to perform the simulation. Two attached cubes of different sizes were created, with the small cube representing the rock/concrete block and the large cube representing cliff/concrete base. The contact between the two blocks was represented by a third fine block in which its properties can be adjusted to change the stability of the rock block to the desired level. For that reason, three models were developed with different bonding lengths as shown in Table 1. Other properties of the bonding material such as cohesion and tensile strength were reduced to be less than that of the small and large block then kept constant in all models during the simulation, therefore, the larger the bonding length the more the block is stable and the shorter the length it is vice versa. Both models were subjected to the same wave intensity for 1 second in a dynamic mode of Flac3D and their response was monitored, Fig. 2 shows the setup.

3. RESULTS OF SIMULATIONS

As stated before, models were subjected to a sine wave for 1 second and monitored throughout the dynamic time of 5 seconds, however, focused on the post wave energy transmission behavior, It was observed that models had different wave responses, case1 displayed a velocity waveform with less reduction in the

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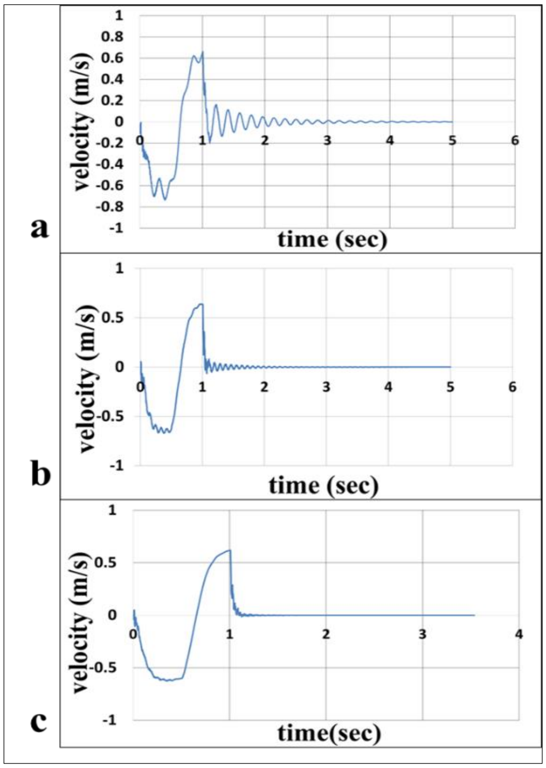

Figure 3 Velocity vs Real-time for dynamic problems: (a) Case1 bonding length of 0.5m; (b) Case2 bonding length of 1m; (c) Case3 bonding length of 1.5m

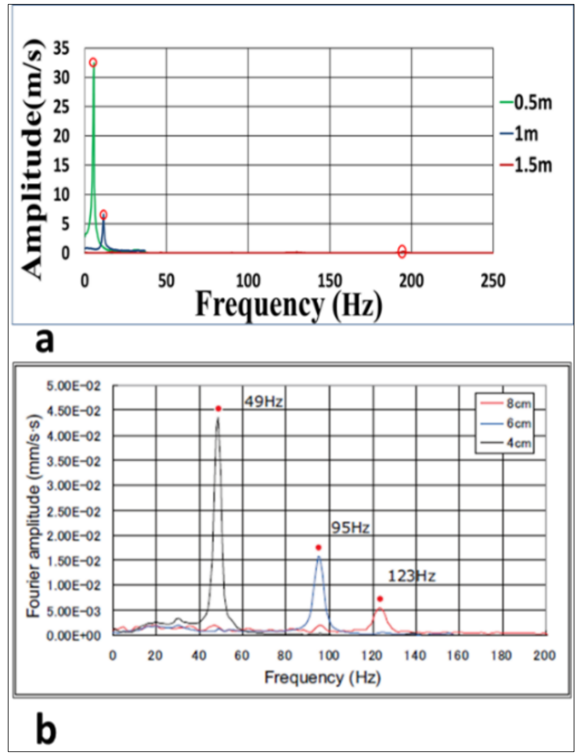

Figure 4 FFT results of two methods: (a) FFT from the numerical method; (b) FFT from the empirical method. (Saito, et al., 2011).

amplitude over the 5 seconds duration than other models and also these amplitudes were much larger than other cases. In contrast, waveform of case 3 displayed quite low amplitudes, with high damping, see Fig 3. Fast Fourier Transform (FFT) analysis confirmed the large amplitudes for the unstable model but revealed that these amplitudes are at low frequencies, on the other hand, stable block showed low amplitudes at high frequencies as shown in Fig.4 (a).

4. COMPARISON OF NUMERICAL AND EMPIRICAL RESULTS

On the analysis of both numerical and empirical results, it was apparent that results are similar quantitatively. Figure 4 shows the results from the two methods; the unstable models tend to have higher amplitudes at low frequencies and these changes with more stable models where amplitudes get reduced and frequencies increase. These trend in the amplitudes and frequency is brought about by the level of stability in the block because the unstable blocks have less restriction in movement due to small bonding surface area and result in weak bond. Therefore when they receive excitation energy from the wave it will take more time for their oscillations to decay until rest. Concurrently these oscillations will be defined by high amplitude that take a while to decrease and return to rest, therefore, leads to few number of complete cycles in other words that are at low frequencies and long wavelength. The outcome differs in stable blocks situation as oscillations take less time to decay to rest due to the restrictions of movement since the bonding surface area is large. The vibrations here can only make oscillations with progressively decreased small amplitudes that complete cycles in a short time also see Fig 3 (c).

5. CONCLUSION AND FUTURE WORK

Two different techniques used vibration to evaluate and analyze the stability of a rock block have been presented. Both results had similar vibration waveform trends in terms of velocity, amplitudes, frequency and damping. In a nutshell, the way the energy is dissipated in unstable and stable blocks is different and it can be illustrated by analyzing the vibration waveforms of each stability condition thus vibration could be used as criteria to evaluate stability. It should be noted that the results from these methods by far are qualitative therefore requires further investigation for quantitative output.

References

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