NUMERICAL SIMULATION OF ROCK BLOCK STABILITY USING VIBRATION RESPONSE FOR MONITORING ROCKFALLS

Utsunomiya University student member ○Tumelo Dintwe
Utsunomiya University member Takafumi Seiki

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 (Ramsden, 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 to investigate the vibration characteristics of rock blocks as precursors, using hammer to generate vibrations and U- Doppler to measure them. 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 a single pulse to comprehend the effects of the mechanical stability on vibration characteristics. Results were then compared with findings from empirical experiments.

2. SIMULATION OUTLINE

A numerical program Flac3D was used to perform the simulation. The setup used in the laboratory experiment was created in the FDM program, as shown in Fig. 2, with the small cube representing the concrete block fixed on a large concrete base. The contact/adhesive 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, two models were developed with different bonding lengths as shown in Table 1, similar to the lab experiment. Other properties of the bonding material such as cohesion and tensile

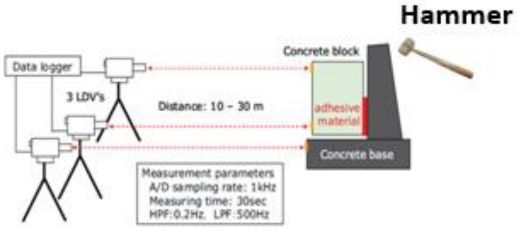

Figure 1 Schematic diagram of the measuring system in the laboratory, edited from (Saito, et al., 2011)

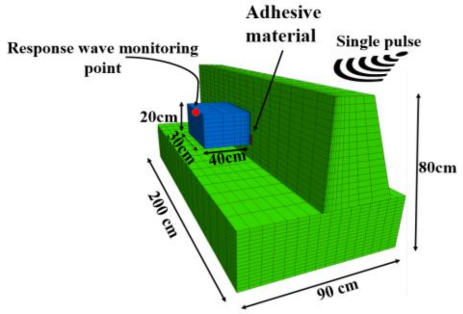

Figure 2 Setup model for numerical analysis.

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

Property	Case1	Case 2
Bonding length	4cm	6cm
Strength	low	medium

strength were reduced to be equal to the plaster used by Saito, et al., 2011, 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. All model cases were subjected to the same pulse intensity to representing the hammer at the same time in a dynamic mode of Flac3D and their response was monitored

3. RESULTS OF SIMULATIONS

As stated before, models were subjected to a single pulse for 0.002 seconds and monitored throughout remaining dynamic time, however focused on the post pulse energy transmission behavior. It was observed that models had different wave responses, case1 displayed a velocity waveform with less reduction in the

Rockfall, Numerical analysis, Vibration
Utsunomiya University, Graduate school of Engineering,
Rock Mech. Lab. 028-689 -6218, E-mail:mt166474@cc.utsunomiya-u.ac.jp

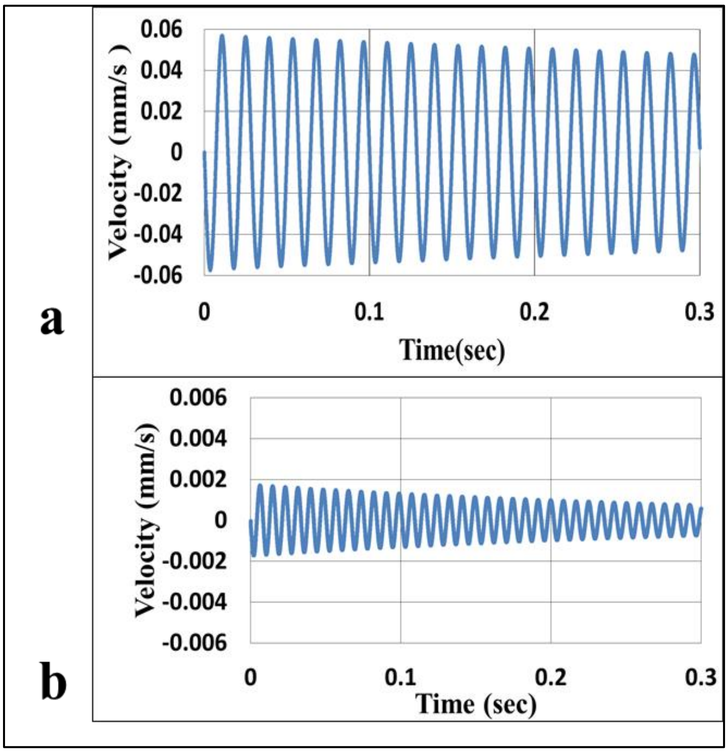

Figure 3 Velocity vs Real-time for dynamic problems: (a) Case1 bonding length of 4 cm; (b) Case2 bonding length of 6 cm.

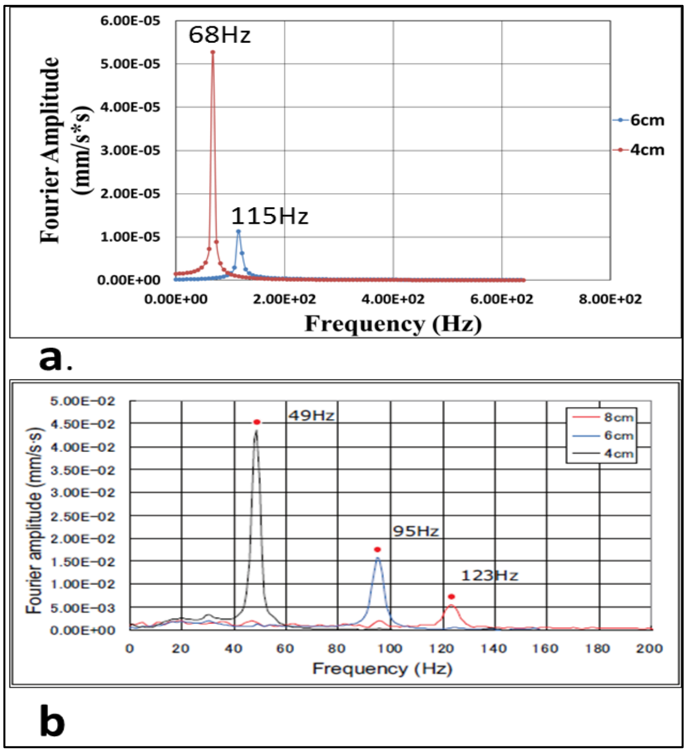

Figure 4 FFT results of two methods: (a) FFT from the numerical method; (b) FFT from the empirical method. (Saito, et al., 2011).

amplitude over the 0.3 seconds duration than other model and also the amplitudes were much larger than other case. In contrast, waveform of case 2 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 (b).

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. Qualitatively the frequency results are in agreement but quantitatively difference in frequencies in both methods is around 10 to 20Hz, therefore numerical models should be developed with a fine mesh in order to get more accurate results quantitatively and also develop a model with 8cm bonding length for clear comparison.

References

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