FULL-SCALE IMPACT EXPERIMENTS ON SOIL

MEASUREMENT OF DECELERATION OF ROCKFALL

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INTRODUCTION

In mountain regions in Switzerland many earth dams reduce the risk caused by falling rocks. To stop the rocks very high forces have to act in the dam. These forces are not exactly known and there is no general function to calculate these forces. With large-scale experiments we have measured the deceleration of falling concrete blocks during the penetration in the ground layer with different thicknesses. With the results of the measurements we gained important values of deceleration peaks, time and penetration depth. Moreover with the measurements we got a look on the characteristics of the deceleration process. There are significant differences between impacts on compacted or non-compacted soil. The maximum of deceleration is to find during begin of penetration for compacted layer and more close to the end of penetration process for non-compacted layer.
The results show furthermore the correlation between the impact velocity and the maximum value of deceleration and other interesting relations.

Fig. 1 8'000 kg concrete block in the full-scale test site Walenstadt.

EXPERIMENTAL SET-UP

Three Blocks with different weights (800 *kg*, 4000 *kg*, 8000 *kg*) were dropped from varying heights (2.5 *m*, 5 *m*, 10 *m*, 15 *m*) on ground layer with different thicknesses (0.5 *m*, 1 *m*, 1.5 *m*, 2*m*) banked up above bedrock. Almost every combination of weight, falling height and ground layer has been repeated three times. In total 132 test were executed, a number of 108 on not compacted ground layer and 24 with compacted layer. A range of kinetic energy from 20-1200 kJ was used (Fig. 2).
Every test has been recorded by 6 co-linear acceleration sensors. The range of two sensors was ±100 *g* and the other four measured up to ±500 *g* with *g* being the gravity constant. The measurement interval was 3 *sec* at a sample rate of 5 *kHz*. The level of the block on the ground layer was measured by leveling instrument before and after the impact. The difference of these values delivers a first value of plastic penetration depth.

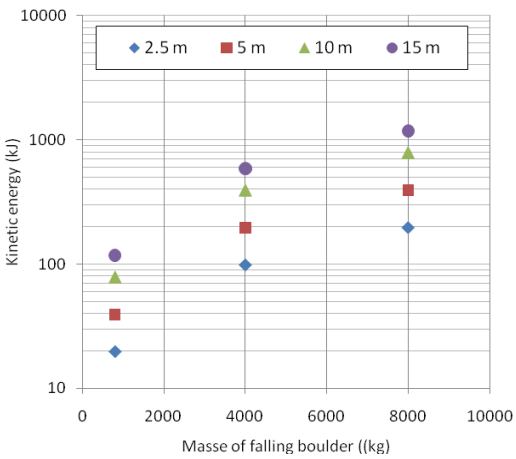

Fig. 2 Kinetic Energy of concrete blocks by different falling heights

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DATA ANALYSIS AND OBTAINED RESULTS

In theory the mean value of the six sensors should be exact 9.81 m/s^2 in stopping position and zero in free fall. Usually, the measured accelerations differ from that. We therefore could calibrate first the measured values to these two absolute terms. Then we integrated the deceleration to obtain velocity and displacement curves of the concrete block. Maximum velocity was reached at the time of the impact and decreases to zero at the point of the maximum penetration depth. To gain the maximum value of deceleration we used a moving mean of the measured values over 2 ms (11 values). This procedure allowed us to compensate the high frequency vibrations measured (5 kHz).

The results of the maximum deceleration and the penetration depth show a correlation with the velocity of the block: the faster the velocity the higher deceleration and penetration depth. With the non-compacted ground layer the maximum deceleration was between 300 - 2000 m/s^2 and the penetration depth between 4 and 24 cm (Fig. 3).

The tests on compacted ground layer show higher maximum decelerations and lower values of penetration depth. The effect of compacting is clearly visible and the deceleration curves vary significantly. During the test, also an un-compacting process can be observed and measured by testing the ground's ME-value. These topics will be presented and discussed more in detail. First results can be found discussed in Gerber and Volkwein (2010) and Schellenberg et al. (2006, 2007)

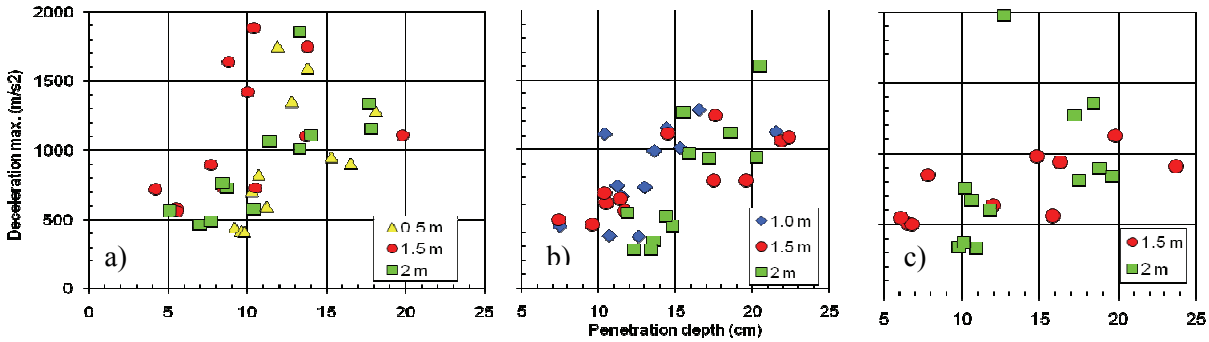

Fig. 3 Deceleration and penetration depth with non-compacted soil due to impact of a) 800 kg, b) 4'000 kg and c) 8'000 kg

DISCUSSION

With this series of experiment we gained important results on the deceleration process of impacting blocks. We find out a new formula to describe the correlation between the impact velocity, the penetration dept and the maximum deceleration. The obtained results help to better design earth dams against rock fall. Additionally, valuable data are produced in order to improve and/or calibrate trajectory simulation of rock fall models.

REFERENCES

Gerber W., Volkwein A. (2010) Impact loads of falling rocks on granular material. In: Darve F.; Doghri I.; El Fatmi R.; Hassis H.; Zenzri H. (eds) Euromediterranean Symp. on Advances in Geomaterials and Structures. 3rd Edition, Djerba. 337-342.

Schellenberg, K., Volkwein, A., Roth, A., Vogel, T. (2006) Rockfall - Falling weight tests on galleries with special cushion layers. In: Manjorana C., Salomoni V., Lok T.S. (eds) Proc. 3rd Int. Conference on Protection of Structures against Hazards. 28-29 September 2006, Venice Italy. 251-258.

Schellenberg K., Volkwein A., Roth A., Vogel T. (2007) Large-scale impact tests on rock fall galleries. In: Huang F.L., Li Q.M., Lok T.S. (eds) Proceedings of the 7th International Conference on Shock and Impact Loads on Structures. 17-19 October 2007. Beijing, China. 497-504.

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