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Impact loads of falling rocks

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Depending on the chosen protection system the planning engineer has to proceed differently. If the impact energies stay below 3'000 – 5'000 kJ solutions using flexible protection systems are recommended in many cases being the most efficient solution. Since 2001, such systems are type tested in Switzerland. The results are published on the internet (www.umwelt-schweiz.ch/typenpruefung). Therefore, the engineers can concentrate on the design of the anchorage and do not need to consider the brake down process of the falling rock because its details including the acting forces within the barrier are given.
This is different to the design of rockfall protection earth dams. Here, the evidence of the structural safety is the major task and questions like the following ones have to be answered:
What magnitude are the forces that have to be carried for a certain kinetic energy? How are the forces influenced by mass or impact velocity? What is the influence of the soil properties such as strength, density and friction angle? How deep does the rock penetrate?
Previous research on the impact loads on the cushion layer of protection galleries were performed by EPFL in the mid-nineties and led to a Swiss Guideline (ASTRA/SBB 1998) to calculate an equivalent static load for the structure underneath. This approach also delivers a function to predict the penetration depth.
This contribution now checks whether above approach can also be used to design earth dams or how it can be modified. For that, the results of previous experiments performed by different institutions were analysed and, if possible, compared to the guideline. This could confirm above mentioned function to predict the penetration depth.
In addition, an experimental series with different bodies (800 kg, 4000 kg) falling from different heights (2 – 15 m) on differently conditioned soils were performed. Measurements were taken through accelerometers attached to the blocks and measuring the vertical deceleration. The penetration into the ground was obtained by using digital high-speed video recording during the experiments and surveyor's optical level before and afterwards. The combination of accelerometers and digital high-speed video recordings additionally allows for a check of the function of the single systems. The rock's velocity can be obtained on the one hand through integration of the accelerations and on the other hand by differentiation of the video data; both values should differ not too much.
Finally, the analyses of the test series enabled a calibration of an improved individual load model for the impact of falling bodies into more or less compacted soil and revealed that the loads resulting from the previous guideline can be reduced by 20%. However, because the maximum impact energy was 600 kJ further experiments are recommended to enable a prediction of the performance for energies higher than 5'000 kJ - an energy sector dams are normally used for.