ON THE EVALUATION OF ROCK FALL PARAMETERS AND THE DESIGN OF PROTECTION EMBANKMENTS – A CASE STUDY

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INTRODUCTION

To protect built-over areas and traffic infrastructure in alpine areas from rock fall with high energies (> 3000 kJ) protection embankments are used. Essential parameters for the design of such protection embankments are geometrical data as the structure height and the lateral dimension as well as the capability to withstand an impact of a rock with a certain amount of kinetic energy. For a real project those parameters have to be determined.

As a first step in the design process rock fall simulation will be done by numerical methods. Those simulations present as a result the trajectory of the falling rocks as well as some “energetic” physical data as for example the kinetic energy of the rock at the impact point on the embankment. While the trajectory of the rock will give direct information concerning the necessary height of the protection embankments, the “energetic” physical data is in general not the required input for the design of the embankment. Therefore the data of the rock fall simulations has to be transformed into data which is usually used in the engineering design. The problems occurred during the complete design process for a protection embankment, i.e. the rock fall simulation as well as the dimensioning of the embankment, will be discussed using the project Obermättli as an example.

THE PROJECT

When the natural hazard map for the village Weggis in Central Switzerland was developed, the area Obermättli, which was declared before as building site, suddenly was assigned to the so-called “red zone”, where the construction of new buildings is no longer allowed. This was due to rock falls, which may occur out of a rock face called Mättli-Felsband. So the natural hazard map not only diminished the value of the property and the investment, which had been already done for the infrastructure in that area, it also constricts the urban development of the village. To use at least a part of the area for further urban development a protection concept has to be developed. The main part of that protection concept is the installation of a protection dam, which prevents the area behind it from rock fall. A special challenge for the design and installation of a protection embankment is given by the steepness of the fall of ground in that area.

ROCK FALL SIMULATION

The rock fall risk specified in the natural hazard map for the area has been developed by using the rock fall simulation program ROCKFALL (Spang). Therefore it seems self-evident to use the same program for further studies, which should be the basis of the design process for the protection embankment. At first calculations had been done by using input parameters in the range of the already done simulations respectively laying in the interval given by the program developer as typical input for the defined surface types. The received results, especially bouncing heights and rock velocities, seemed to be untypical for the examined profiles. Therefore additional simulations had been done by using the Colorado Rock-fall Simulation Program (CRSP, v 4.0). In this case input parameters have been used which are described as typically by several authors (an overview concerning those parameters is e.g. given by Heidenreich, 2004). With those calculations more realistic bouncing heights have been achieved.

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In January 2010 a block with a diameter of approximately 1.1 m was dropped during tree cutting work at the so-called Mättli-Felsband. Most of the impact points of that block could be surveyed on the slope. This incident was chosen to do a back analysis and to find out the values of the input parameters for the program Rockfall. This resulted for example in values for the normal damping factor Dn which are 5 to 8 times larger than the values used for the first calculations. With the input parameters found by the back analysis calculations have been done for 4 profiles in the project area.
The calculations showed also that at some places the knowledge of the thickness of the rock-covering soil is very essential for the simulation results. Therefore additional at a part of the project area dynamic probing had been done to find out the thickness of the rock-covering soil layer.
According to the results of the rock fall simulations we found out, that a protection embankment along the building site Obermättli should have a height between 3 to 3.6 m. With such a protection embankment the following scenarios for the building site are given:

- Rockfall with block diameter larger 2 m: less than 1 in 35'000 years.
- Rockfall with diameter 0.5 m to 2 m: less than 1 in 10'000 years.
- Rockfall with diameter less than 0.5 m: less than 1 in 5'000 years.

This probability of occurrence seems to be acceptable.

PROTECTION EMBANKMENT DESIGN

Conventional design methods are based on forces and loads. Therefore for dynamic problems in civil engineering very often a formula is used to transfer the "energetic" data into a force, which can be used for the further design process. In Switzerland for the design of rock fall protection structures in general a formula is used, which originally was developed for the design of soil-covered sheds and is documented in the ASTRA guidelines (ASTRA, 2008). This formula gives interrelation of the kinetic energy of a block to an equivalent force.
But this formula has been developed empirically for the geometry and the boundary conditions of a rock fall on a concrete plate covered by a layer of soil with a well-defined constant thickness e. In the case of an impact on an embankment, geometry and boundary conditions are different. Especially the definition of a layer thickness e analogous to the soil-covered shed is delicate. Fig. 1 shows the forces derived by using the "ASTRA-formula" for 2 different values of e as well as the results of some other models in comparison. For the project the forces vary up to a factor of 5 for the different formulas.

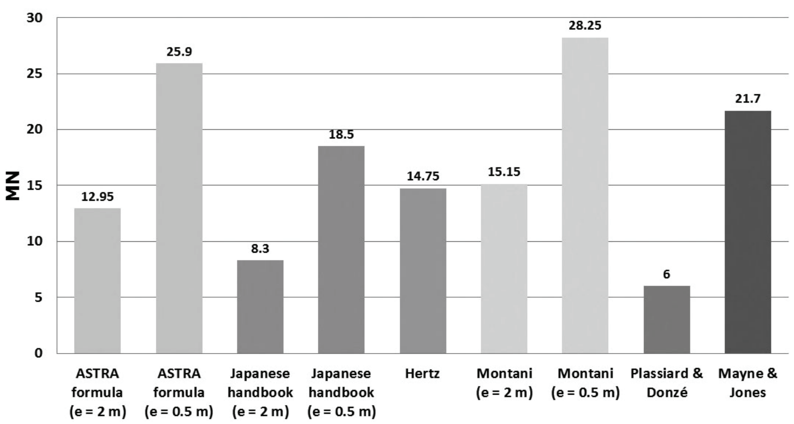

Fig. 1 Equivalent force method – comparison of different models

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