Loads on post foundations of rockfall protection fences

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INTRODUCTION

The former Swiss (Gerber, 2001) and the actual European (EOTA, 2008) guideline for flexible rockfall protection barrier do not consider the design of the foundations for the steel posts of the barriers. Instead, the design of the foundation is done by engineering calculations based on experience and deduced from the loads that are measured at the barriers ropes during type testing according to above guidelines. Especially, if the posts not only transfer pressure loads (hinge support and kept in place using upslope ropes) but are clamped supported. In this case, bending moments and also tension forces are transferred to the foundation which has to fulfil the safety requirements according to valid standards. Additionally, ropes that are connected to the post's ground plate impose additional lateral forces to the foundation which usually are not known.

First approaches have been developed in the last years (full description in Volkwein et al., 2016) that deliver data on single loads on the foundation. We present a newly developed measurement device that is capable to measure the loads in all six degrees of freedom that are transferred from the post-groundplate-kit to the ground. For the first time, the design of the foundation for the groundplate can be done on validated data directly based on measurements of full scale barrier field respective approval tests.

In this extended abstract we shortly present the setup of the developed measurement device together with its handling and first test results.
A special in-situ calibration procedure is proposed which accounts for the more or less fix installation of the device in the field.

MEASUREMENT SETUP

Different criteria had to be considered for a robust measurement device to successfully obtain suitable and reliable data during field tests. The loads that are expected might reach 1'000kN orthogonal and 300kN parallel to the ground. The torque loads of 300kNm should be measurable as well. The installation takes place on a nearly vertical rockface in the field. So, the final configuration must withstand temperatur influences as well as rain, snow and other weather conditions. The device has to be mountable to the existing foundations in the field and the limited geometrical conditions on the rockface reduce the spatial dimensions available for the device.
The measurement device consists of four 3D load cells that are installed between two massive steel plates at their corners (see Fig. 1). Altogether 12

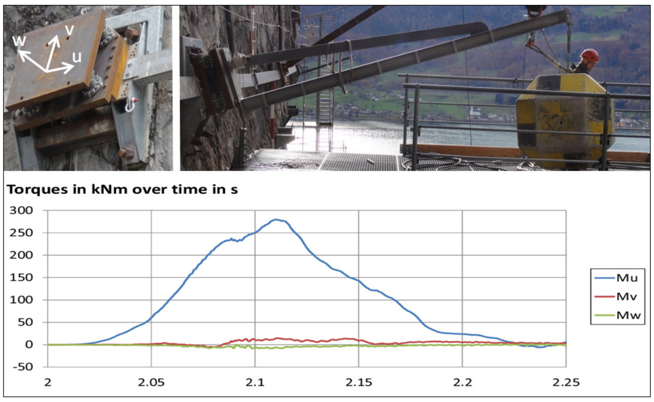

Figure 1. (upper left) Installed measurement device with (upper right) attached steel post vertically loaded by a concrete block. (Lower) Measured torques over time during testing of a rockfall protection fence.

sensor channels are available with four in each main direction. In order to protect the measuring cables, the load cells have been turned by 90° from corner to corner so that the cable outlet direct to the inner centre of the device. The measurement amplifiers and the data recording unit are placed in a distance of about 50m. There, the measurement system is connected to the remaining measurement equipment which is usually in use during a field test of a rockfall barrier, i.e. high speed video cameras and a load cell measurement system for the loads in the barrier's steel cables. This connection enables a synchronous trigger of all systems. Sample rate of the new measurement device is up to 10kHz. The combination of the load cells and the steel plates reacts sensitive on distortion during mounting. Therefore, the existing foundation has been digitally scanned with a precision of 0.01mm to enable the production of a perfectly fitting steel bar that is placed between measurement system and the foundation on the rockface.

DATA ANALYSIS

After measuring the intended loads directly below the ground plate are determined through different mathematics/matrix operations as shortly listed in the following.

1. Conversion of single load cell orientations to overall coordinate system.
2. Decoupling of single channels of each 3D cell
3. Determination of loads in three direction of each load cell
4. Conversion of single measurements into loads with 6 DOF loads for foundation.

POSSIBLE CALIBRATION PROCEDURE

For the calibration of the system we mounted a clamp supported steel post to the sensors and loaded its top in different directions by different forces. The loads measured and calculated by above data analysis procedure are then compared with the loads imposed at the post head. The torques are retrieved through the vector product of the force vector and the distance vector from the centre of the steel plate to the post head. The data obtained are then put into a large equation system that allows the determination of the conversion coefficients through a regression analysis. The result are the forces and torques (see Fig. 1) acting on the ground over time. Especially the plate parallel forces and the torque around the w-axis are new values never measured before.

CONCLUSION

A new measurement has been developed for the use with rockfall protection barriers that can stop falling rocks (e.g. 3200kg at 25m/s). The device will deliver valuable data enabling a design of the foundations for the barrier's steel post. Experiences with its handling, usage limits and measurement results from calibration and field tests are part of the full contribution.

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KEYWORDS

Rockfall; flexible protection systems; foundation; loads; measurement device

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