SWISS GUIDELINES FOR THE APPROVAL OF ROCKFALL PROTECTION KITS – 7 YEARS OF EXPERIENCE

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Since the introduction of the Swiss Guideline in 2001, flexible rockfall barriers consisting of wire nettings and steel posts have been systematically tested. This now results in seven years of experience concerning type-testing and the mechanical properties of individual structures but also on measuring procedures and data. In accordance with the guideline, the barriers were dynamically tested by free-falling test bodies and characterized by energy absorption classes ranging from 250 kJ to now 5000 kJ. For each test a number of different data were gathered before, during and after the actual impact. This includes forces acting on the supporting ropes, wire netting deformations and brake times and distances of the test specimen.

Keywords: rockfall protection, guidelines, type testing, experience

INTRODUCTION

In 2001 the Swiss Guidelines for the approval of rockfall protection kits [1] became operative as the first governmental guideline worldwide. It was the result of 13 precedent years of field testing of flexible rockfall barrier systems. As also written in [2, 3] various types of wire nettings of various constructions have been developed in Switzerland. In order to enable a quantitative assessment of their respective characteristics and qualities, the Swiss Federal Office for the Environment, BAFU, which subsidizes these protective measures, has issued guidelines for the testing of wire nettings that protect against rockfall. So far eighteen different types of wire nettings have been submitted for tests, fifteen of which succeeded in complying with the norms set by the guidelines. In this report we present individual test results that may answer various theoretical and practical questions. It will be shown that a relationship exists between the kinetic energy of the impacting stone and the deformation of the protective net, varying with the length of the trajectory and the moment the falling body was first braked. These data enable us to evaluate the degree of stiffness or softness of the braking process (abrupt- / gentle braking processes). The results shown in this contribution can be found more detailed in [3].

METHODS

In order to test the capacity of wire net barriers under realistic conditions, a test facility that meets certain requirements is needed. Stones falling from slopes mostly move in a bouncing motion. Maximum velocity of the stones occurs at the end of the trajectory, shortly before they hit ground. Previous research has found that the impact angle of the trajectory is often about 15° greater than the angle of the slope [4]. When these premises are applied to various slope angles, the relevant test conditions may be derived from them (see Fig. 1). The experience resulting from different tests on different slope arrangements has proven that a vertical

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test installation also enables test circumstances ‘approaching nature’, provided the correlations between the slopes remain the same. This means that the protective nets in a vertical test setting have to be mounted at an angle of 30° to the horizontal.

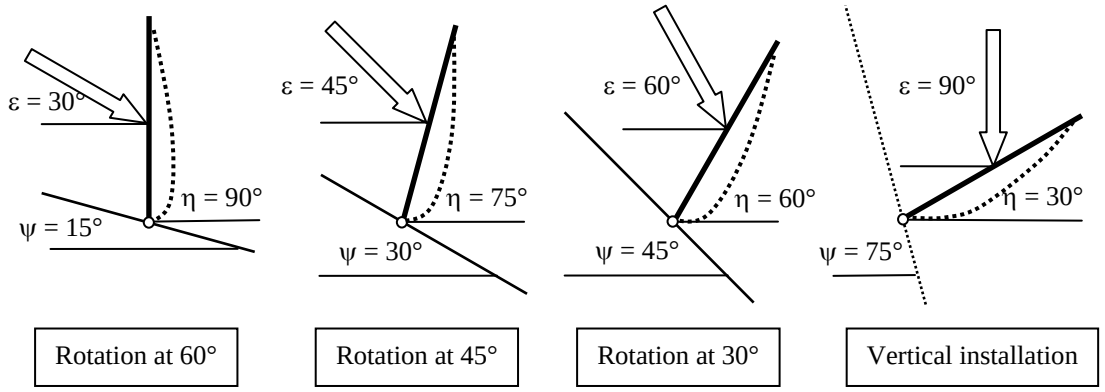

Fig. 1 Schematic representation of various sloping arrangements and a vertical arrangement. Rotation in respect of vertical installation.

In the test facility Lochezen at Walenstadt the examined protection systems are mounted on an almost vertical slope, four steel posts attached on foundation bases with three fields of 10 m width. The post heads are retained by retaining ropes, the support ropes along the barrier hold the net. Depending on net type, the support ropes usually contained incorporated braking elements in order to keep the impact forces at a predetermined level and to slow down any further increase of these forces. Measuring cells are also incorporated in the ropes in order to register these forces (Fig. 2) sampled with 2000 kHz during the test. Additionally, the movements of the bodies falling into the net as well as the resulting deformation of the net are filmed with high-speed cameras (250 frames / sec). The cameras are activated by the same signal that triggered force measurement..

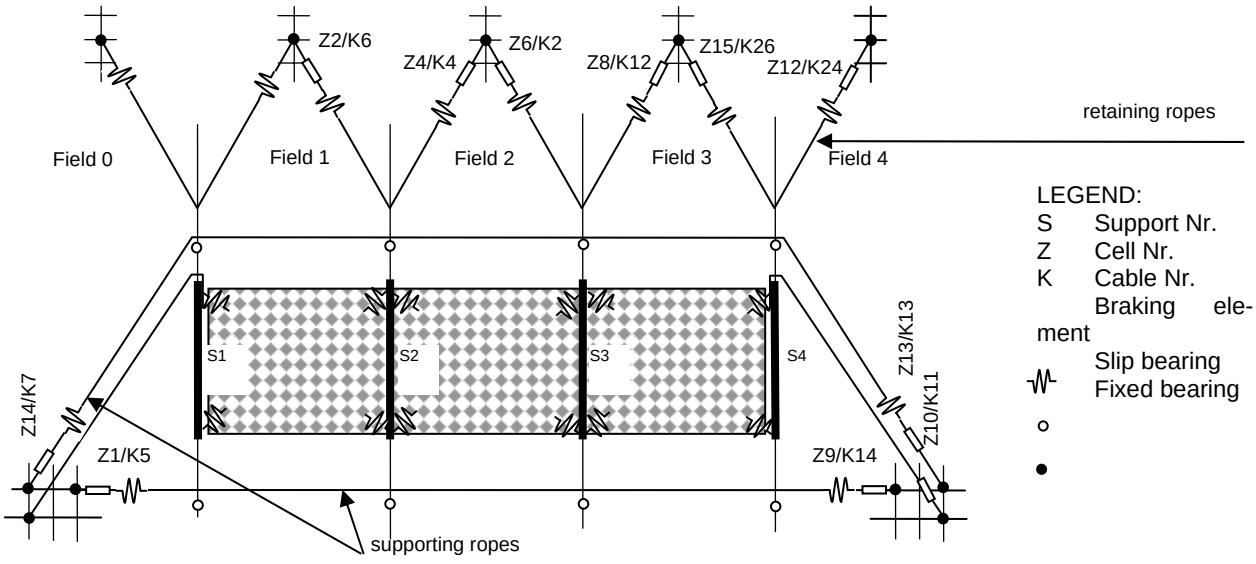

Fig. 2 Schematic positions of the supporting elements and the measuring cells.

A type-testing procedure consists of the following subtests:

a) Small energy tests (test bodies with a lateral length of 10 cm, 20 cm, and 50 cm); to test the deformations of the laid-on mesh

b) 50% energy tests (test bodies with 50 % mass); to establish the required repair effort
c) 100% energy tests (test bodies with 100 % mass); to test bearing capacity and deformability
d) Tests according to special criteria; to test the practical suitability

RESULTS

So far, out of 18 type tests, 15 net types have turned out to comply with the guidelines and so are eligible for subsidy by the Federal Office for the Environment. The most important test results from the published data in the relevant certificates (http://www.umwelt-schweiz.ch/typenpruefung) are summarised in [1]. They are the results concerning the following issues:

- The braking process of the falling bodies (braking distance and braking time)
- Maximum forces on the upper and lower supporting ropes and the retaining ropes
- Net height and remaining effective height of the net's centrefield (field 2)
- Labor required for repairs, in working hours after a 50%-test

Fig. 3 shows the brake times and distances as well as the maximum load on the retain ropes as an example for the measurement values. More results will be shown and discussed in the presentation.

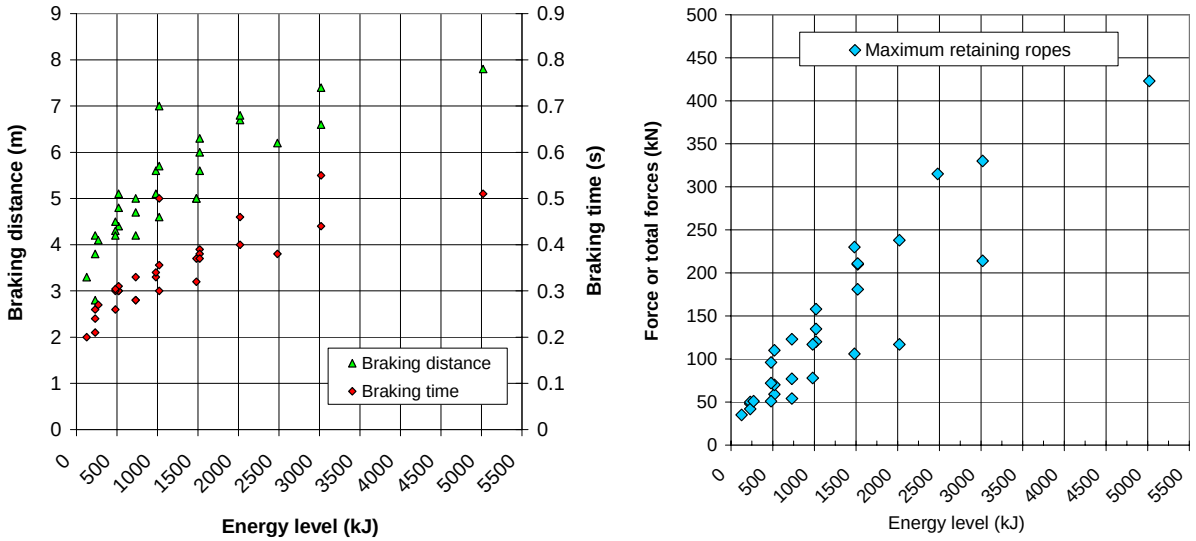

Fig. 3 Increase of braking distance and braking time of the falling bodies in the protective net in proportion to kinetic energy and measured maximum load in the retain ropes.

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