FORCES ACTING ON ROCK-FALL PROTECTION MEASURES

PARTIAL FACTOR OF SAFETY-APPROACH TAKEN BY THE AUSTRIAN STANDARD
ONR 24810: TECHNICAL ROCKFALL PROTECTION

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INTRODUCTION

The Austrian Standards Institute in cooperation with the Austrian Service for Torrent, Avalanche and Erosion Control is publishing several Austrian Standard Rules (ONRs) dealing with the assessment of natural hazards and the design of protection measures. All published ONRs are developed in compliance with the relevant EUROCODES. Therefore the concept of partial factors of safety for individual treatment of tolerances abundant in the assessment of actions and resistances of constructions or the underground bearing the foundations, is one of the key features of the new ONR 24810 "Permanent Technical Protection against Rock-Fall". In this Austrian Standard Rule special emphasis is given to the assessment of the forces developed by rock-fall processes and their interaction with protection measures.

AUSTRIAN STANDARD RULES (ONR)

The ONRs dealing with natural hazards such as torrents, avalanches and rock-falls are developed by working-groups implemented by the Committee “Protection from Natural Hazards”. An Austrian Standard Rule (ONR) is a national guideline which requires a restricted consultation and commenting process including a limited number of experts and organizations as compared to a national standard.

ONR 24810 "PERMANENT TECHNICAL PROTECTION AGAINST ROCKFALL"

This new Austrian guideline is dealing explicitly with two mayor types of mitigation measures:
- Primary protection measures preventing rock-fall detachments (e. g. anchoring)
- Secondary protection measures in the rock-fall path such as
  - Rock-fall protection fences
  - Rock-fall protection dams and ditches
  - Rock-fall galleries
  - Protection measures integrated in static structures (e. g. damping layers on roofs)

Rock-fall protection achieved by land use planning is not part of ONR 24810.

For all the types of mitigation-measures forces acting on the constructions are assessed individually. To account for the natural variation of the parameters leading to the respective actions encountered, the design-forces are subject to partial factors of safety to fulfil the general condition:

\[ E_d \leq R_d \]

with

\[ E_d \] … design capacity (energy) or design value of the effects of actions on the mitigation measure
\[ R_d \] … design value for resistance of the mitigation measure

\[ E_d = E_k \cdot \gamma_E \]

with \( \gamma_E \) partial factor of safety for action

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According to EUROCODE 0 depending on the consequences class of the protected infrastructure, different probabilities of failure are to be accepted:

**Table 1:** Consequences classes [based on Table (B1) – EN 1990]

<table>
<thead>
<tr>
<th>Consequence Class</th>
<th>Description</th>
<th>Examples of buildings and civil engineering works</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC1</td>
<td>Low consequence for loss of human life, economic, social or environmental consequences small or negligible</td>
<td>Agricultural buildings where people do not normally enter (e. g. storage buildings, greenhouses)</td>
</tr>
<tr>
<td>CC2</td>
<td>Moderate consequence for loss of human life; economic, social or environmental consequences considerable</td>
<td>Residential and office buildings, public buildings where consequences of failure are medium (e. g. an office building)</td>
</tr>
<tr>
<td>CC3</td>
<td>Serious consequences for loss of human life, or for economic, social or environmental concerns</td>
<td>Grandstands, public buildings where consequences of failure are high (e. g. a concert hall)</td>
</tr>
</tbody>
</table>

**Table 2:** Accepted probability of failure depending on consequences classes (according to Table (C1)-EN 1990 in combination with Table (B2)-EN 1990)

<table>
<thead>
<tr>
<th>Consequence Class</th>
<th>Probability of failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC1</td>
<td>1*10⁻⁵</td>
</tr>
<tr>
<td>CC2</td>
<td>1*10⁻⁶</td>
</tr>
<tr>
<td>CC3</td>
<td>1*10⁻⁷</td>
</tr>
</tbody>
</table>

**Actions and Resistances in the Concept of Partial Safety Factors**

The forces determined as acting on the different protection measures \((E_k)\) are to be multiplied with partial safety factors to compensate for the uncertainty of the investigation procedure leading to the design-forces. On the other hand the resistance (e.g. determined by technical approval) of protection structures has to be reduced by dividing the resistivity \((R_k)\) by the partial factor of safety. The determination of the forces to be expected acting on the protection structure are to be executed using tools which represent the state of the art. Therefore the application of physical rockfall calculation methods is obligatory nowadays. How to process the results produced by those software-tools will be discussed in the presented paper.

**Challenges to Fulfill the Principles of the Eurocode 0 (EC 0)**

The EN 1990 is intended to be used in conjunction with EN 1991 to EN 1999 for the structural design of buildings and civil engineering works, e.g. geotechnical aspects, situations involving earthquakes, execution and temporary structures. Although the regulations of the EC 0 are not appropriate for the design of protection measures related to natural hazards, it is applicable for the design of structures where other materials or other actions outside the scope of EN 1991 to EN 1999 are involved. The statistical principles in the EC 0 mainly refer to distribution functions, which do not correspond to conditions observed in geological systems. They are rather focusing on production-systematic errors and related functions. Neither the application of mean values nor normal distributions were appropriate for the determination of failure probabilities within the range of extreme border probabilities (see Table 2). Extensive calculations of well known case studies were done in order to find a comprehensible rule for the evaluation of rock-fall processes, acting on protection-structures.

**References**

ONR 24810, Permanent technical protection against rockfall
ÖNORM EN 1990, Basis of structural design

**Keywords:** rock-fall, ONR, technical rock-fall protection, partial factors of safety