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MAINTENANCE OF ROCKFALL NET FENCES

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The efficiency of rockfall protection net fences is affected during their lifetime by damages and ageing phenomena. To identify the main issues that can affect the durability of rockfall protection net fences a site survey campaign has been performed in the North-west of Italy. This campaign aims to point out to the main aspects to focus on for maintenance management.

Keywords: rockfall protection net fence, maintenance, damages, corrosion

INTRODUCTION

The design of rockfall net fences had a big development in the last decades. However, little attention has been paid to the management and maintenance of rockfall protection devices during their lifetime. This is a big concern for public administrations that have to know the state of the protection devices to correctly plan the maintenance and to identify the loss in efficiency to ensure risk mitigation [1]. The rockfall protection devices nowadays present in Italy are a very heterogeneous ensemble of models and types, installed in the last 50 years. The long time span also implies a big variation in standards of design and installation. Therefore, for the public administrations it is a major issue to understand how the rockfall protection devices degrade with time, how to guarantee that the risk mitigation is still effective and when these devices have to be changed with new ones.
In this paper the results of a site survey on 62 net fences in North-west of Italy and a numerical model to simulate the ageing effect on a net fence will be presented. The aim is to point out the main aspects that affect the efficiency of rockfall net fences, in order to give clear indication to the local administrations for maintenance needs and guidelines for design and installation.

CHECKLIST DEVELOPEMENT

A site survey checklist has been developed based on available installation and maintenance guidelines, on standards [2, 3] and on site experience. This checklist aims to be a tool for local administrations for periodical checking of the products. The checklist has been improved by testing on site and has been implemented on an app for mobile devices. This tool has been used for the site survey of the rockfall protection net fences to identify the damages and problems of installation. The checklist is fulfilled with information about the type, geometry and deterioration of the barrier, but also with GPS coordinates of post position and with photos of the damages. This allows to input all the data from the survey on a GIS model and to compare the state of the barrier during different surveying times.

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Fig. 1 - Slid clamps

Fig. 2 - Short upstream rope

Fig. 3 - Long upstream ropes

ROCKFALL PROTECTION NET FENCES SITE SURVEY

During the site survey campaign 62 rockfall protection net fences have been analyzed. The observed defects can be summarized as installation issues (90 %), maintenance issues (19 %) and corrosion (58 %). Hereinafter, the main issues observed during the survey campaign are discussed synthetically. In Dimasi et al. [4] the complete review of the data and the collected check-list have been presented.

INSTALLATION ISSUES

Problems related to installation and design are the most frequent. In several situations, the rockfall protection barriers checked during the survey campaign are not installed in accordance with the installation guidelines. It must be observed that for works installed before the promulgation of ETAG 027 [2], the installation manual was not required. In any case, some discrepancies had been detected between the installed configuration and the available construction drawings.
Moreover, problems related to the quality of the connections using clamps. During the survey campaign the clamps were often found not installed in accordance with the regulations in force [5] in terms of number, distance and closure. The clamp connection shown in Fig. 1 has not worked and the clamps have get close to each other letting the rope slide during the impact. This phenomenon may be connected to an incorrect torque applied to the fastener. Therefore, during the campaign, the torque applied to the clamps was recorded using a torque wrench. These measures show a different behavior of clamps installed on tensioned ropes and on loose ropes. The first ones maintain the prescribed torque in the 95% of the recorded samples while the latter ones have only the 80% of the prescribed torque, even in clamps installed in the last 5 years. This seems to be a key aspect to focus on in order to guarantee the correct behavior of the connection structures during all the life span of a rockfall protection barrier and more studies are needed to analyze the behavior of clamps on net fences.
Furthermore, ETAG 027 [2] prescribes to indicate, in the installation manual, the tolerances and imposes to the designer to perform specific evaluation reports in the case the barrier is installed disregarding those tolerances. Nevertheless, during the survey campaign several barriers have shown a configuration not compliant with the available installation manual. For example, in Fig. 2 one of the upstream ropes is installed sub-horizontal and shorter than all the other due to the presence of a rock slope immediately behind the post. On the contrary, in Fig. 3, the upstream ropes are much longer than what required by the installation manual due to the slope conformation.

MAINTENANCE ISSUES

Several net fences were found filled with material (rock and vegetation) in the net. This highlights a clear lack in the maintenance procedures, also due to the difficulty to reach the rockfall protection devices. This situation obviously reduces the efficiency of the net fence and thus the risk mitigation. During the survey campaign in some barriers, already subjected to maintenance, some problems have been recorded due to maintenance works that have not restored the original configuration of the barrier.

CORROSION OF METALIC ELEMENTS

Even if the barriers detected during the survey campaign reflect a sample of works installed just in the last 12 years and all in mountain environment, corrosion issues have been detected in some of the components. Ropes do not show significant corrosion phenomena; posts and ring nets have corrosion only in the impacted zones while wire rope clamps are sometimes corroded. The elements that more often result subjected to corrosion are the clamps, even in works installed in the last 5 years. The corroded clamps are often randomly diffused on the barrier and corroded and not corroded clamps can be found on the same rope. No clear indication on the trigger event of corrosion has been detected. Therefore, producers should put specific attention and analyses on the corrosion resistance of clamps in order to ensure the duration of the connections.

NUMERICAL SIMULATION

In order to evaluate the influence of the different problems found during the site survey campaign, a numerical simulation of these damages has been performed. A complete presentation of the results of these simulations are reported in Luciani et al. [6]. In these analyses, a numerical simulation of a commercial net fence has been developed and set using the data of real scale tests reported by Gottardi and Govoni [7]. The numerical model has been modified to simulate the damages or ageing phenomena observed during the surveys. Specifically, six modified models were considered to simulate damages to the upstream ropes or to the clamp connections, damages to the anchorages and different installation geometries.
On the modified models an impact test was simulated following the ETAG 027 [2] and the energy withstood by the aged net fence was evaluated (Fig. 4). Thank to these simulations, it was possible to assess define the influence of the different damages and ageing on the efficiency of the net fence.

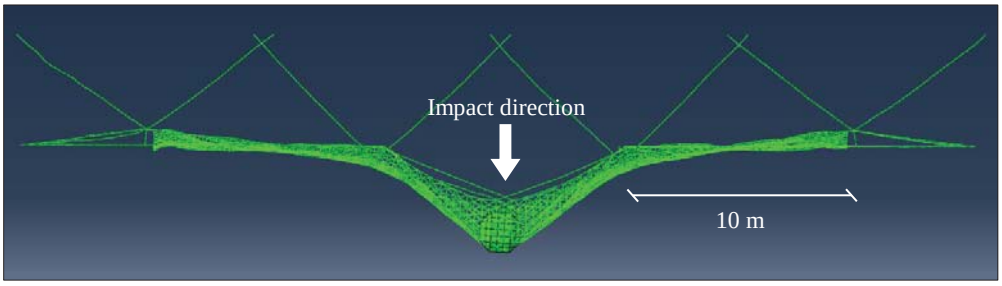

Fig. 4 - Numerical model of the net fence during an impact. It is possible to see that a barrier of 4 posts has been studied.

Tab. 1 – Main results of the simulations expressed in residual efficiency

Problem simulated	Residual efficiency [%]
Failure of one clip connection or of one central upstream rope	100
Failure of one clip connection or of one lateral upstream rope	100
Failure of two clip connection or of the central anchorage	97
Failure of two clip connection or of a lateral anchorage	100
Short and horizontal upstream ropes	80
Long upstream ropes	87

The most important results obtained by the numerical simulation are reported in Tab. 1 where the effect of ageing is represented by the residual efficiency value defined as the ratio between the energy withstood by the aged model and the nominal energy of the barrier.

CONCLUSION

A site survey campaign on rockfall protection net fences in North-west of Italy allowed to assess the main damages and ageing processes on net fences. Many of these damages can be avoided with a careful design and installation of the device. Furthermore, a proper maintenance plan and a timely refurbishment after impact can avoid the reduction of efficiency of the net fence. Particularly the clamps appears to be a weak link in the system, both for their installation and for their durability against corrosion and further studies are needed to analyze this aspect. A numerical simulation of the main damages has been performed to analyze their influence on the efficiency of the net fence and an assessment of the residual efficiency is presented.

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