

BEHAVIOUR OF ROCKFALL SHELTERING STRUCTURES: EXPERIMENTS AND NUMERICAL ANALYSES

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This paper concerns the application and evaluation of the uncoupled design approach for rockfall protection tunnels that has been recently introduced by the authors.

The mentioned approach considers tunnels protected by an absorbing layer of soil, and allows to evaluate the time history of stresses acting on the upper face of the roof of the shelter (usually a reinforced concrete slab) during an impact, starting from the evaluation of the impact force acting at the boulder-soil interface, and subsequently considering the stress propagation through the soil stratum. Considering the dynamic nature of the phenomenon, the complete description of time evolution of both impact force and stress increments is given, in the form of synthetic curves whose parameters depend on the design impact (size of the block, falling height) and on the geometrical and mechanical properties of the absorbing layer (thickness of the layer, stiffness of the soil layer). All these parameters are available to the end-user in the form of design charts, as a function of the mentioned factors.

The reliability of the proposed approach has already been tested by comparing the synthetic diagrams with the results of impact experiments performed on different types of granular layers (namely loose and dense sand), as shown in previous publications.

Starting on this basis, the design approach can be conveniently used to simulate the effects of a number of impacts, by performing a series of dynamic numerical analysis of the behaviour of the shelter where the synthetic stress increments are directly applied to the structure itself as input loads. In particular, the FE code Straus is used for modelling a modular structure made of a series of precast cantilever modules (module width 1,67 m). In this structure, each module is anchored to the mountain side by tendons, and a RC plate is cast in-situ on the modules to connect them and provide continuity in the longitudinal (parallel to the tunnel axis) direction (Figure 1).

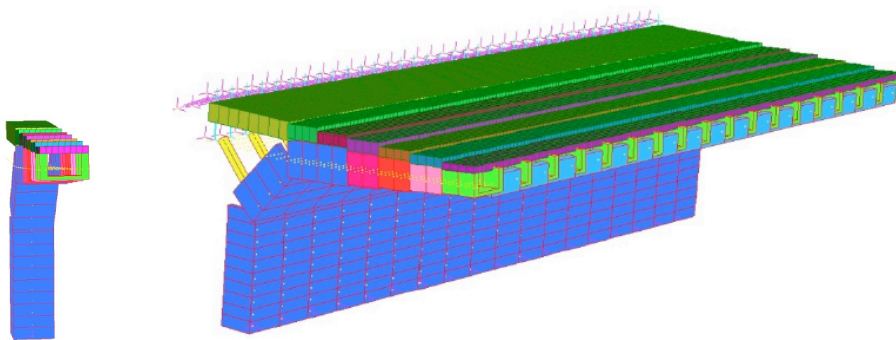


Figure 1: Numerical model of the shelter; one module (left) and assembled structure (right).

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Numerical simulations, which will be complemented by a similar campaign of experiments on a real shelter, are particularly useful for highlighting some relevant aspects of the phenomenon, such as the non-linear effect of the relationship between the duration of the impulse and the natural period of the structure, the separate influence of structural stiffness and mass, and the importance of the size (longitudinal extension) of the structure which heavily affects the 3D response. This effect is due to the behaviour exhibited by the plate under impacts, as qualitatively shown in Figure 2. When only a few modules are assembled the structure essentially behaves as a cantilever beam. On the contrary, for longer shelters, the bending stiffness of the upper plate contributes to diffusing the solicitation transversally (which reduces the maximum deflection, see Figure 3). It is worth to note that in both cases the in-plane stiffness of the plate is such that the plate itself moves horizontally as a rigid body.

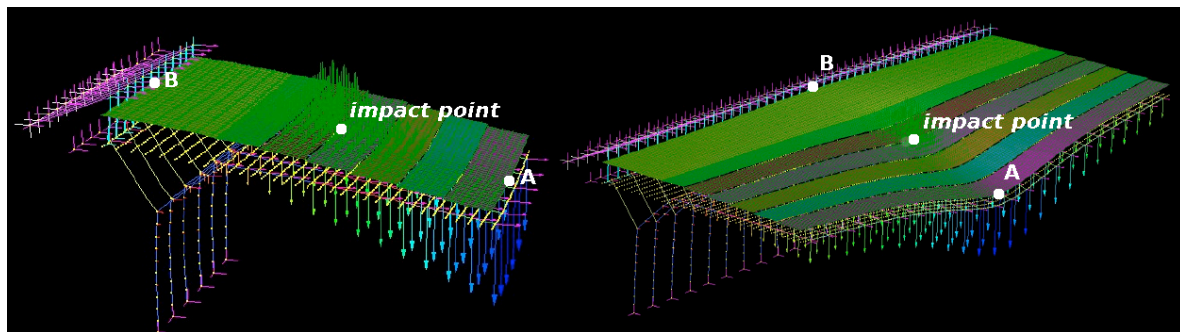


Figure 2: Shelter deformation under impact loads; 6 modules (left) and 24 modules (right).

These effects can be quantitatively studied by plotting the displacements of the plate during impacts as a function of time (Figure 3). Besides the progressive reduction of the maximum deflection at point A, which rapidly becomes constant for shelter length larger than about 30 m (more than 18 modules), it is worth noting that the horizontal displacement of the plate is reduced significantly even for larger number of modules, which is due to the increased number of collaborating anchors.

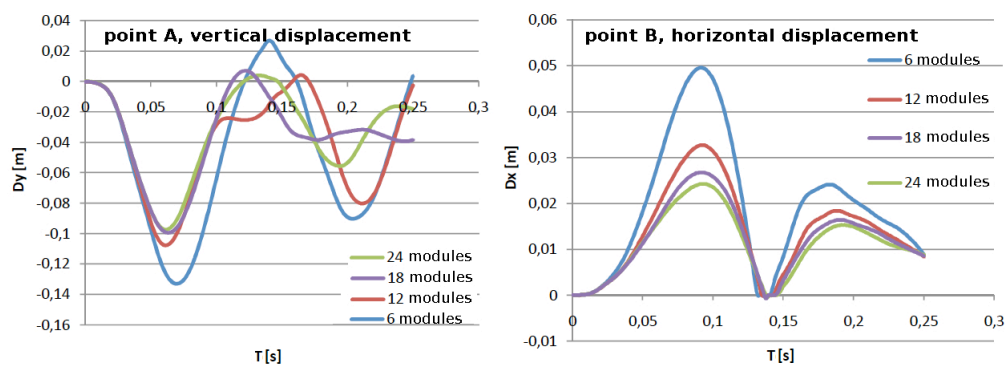


Figure 3: Plate displacements as a function of time