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DESIGN APPROACHES IN ROCKFALL EMBANKMENT

A NEW METHOD TO DESIGN ROCKFALL EMBANKMENTS AT THE SERVICEABILITY AND ULTIMATE LIMIT STATE

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ABSTRACT

The rockfall barriers can absorb extremely high energy levels. Unfortunately, their cost and installation difficulties rise according to the energy level, so that barriers fit to withstand more than 3,5 - 5,0 MJ impacts could be very expansive. In case of high energy level, the embankments are the real cost effective alternative to the rockfall barriers: in matter of facts they resist to multiple impacts with very small downslope deformation, they are environmental friend, and last but not least, their maintenance cost is negligible. That is why in the last years many advancing have been done in order to improve their performance, aesthetic and designing aspects.

Concerning the designing, a large effort has been developed by Officine Maccaferri S.p.A. in cooperation with the Polytechnic of Turin, with the aim to develop a reliable and simple design approach. The result, carried out on the base of previous studies, FEM analyses and case histories, allows the embankment sizing considering its ultimate (ULS) and serviceability limit states (SLS). The first one (USL) helps to minimize the size, whereas the second one (SLS) let foresee maintenance aspects and interference problem with next infrastructures.

GENERAL ASPECTS FOR THE DESIGNING

The design of any rockfall embankment require the following steps: (1) Calculation of the essential impact parameters (velocity, heights and mass of the falling block); (2) definition of the embankment geometry in relation to the dynamics impacts; (3) global and internal stability analyses.

The design should take into account other aspects like for instance (a) slope morphology and general conditions of foundation; (b) volume availability on the upslope side for the fallen rocks accumulation; (c) type and availability of suitable soil for the embankment construction; (d) geometry of the upslope embankment face in relation to the rotational energy of the falling block.

THE NEW METHODOLOGY TO DESIGN A ROCKFALL EMBANKMENT

The most problematic aspect of the designing is the evaluation of the embankment behaviour under dynamic impact. In order to solve it, a wide range of cases was carried out with a finite element software calibrated with the Maccaferri embankment solutions. The research has basically showed three main ways to dissipate energy while the block impacting: (1) Plastic dissipation related to the block penetration into the structure. It amounts to 80-85% of the total kinetic energy; (2) Friction dissipation due the sliding of embankment layers. That sliding gives a certain deformation on the downhill side. It amounts to the 10-15% of the total kinetic energy; (3) Elastic dissipation due to the constipation of the soil while the block impacting. It is next to 1% of the total kinetic energy.

The effects are limited to the layers directly impacted, as shown in figures: the displacement basically involves a truncated wedge which is defined by two sides inclined $\psi \approx 45°$ (fig. 2). The layers displacement and the energy dissipation are influenced both by the block impact footprint and type of reinforcement.

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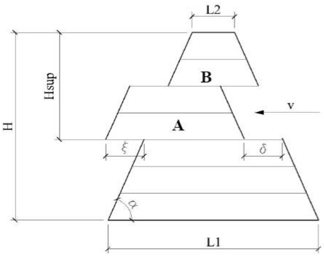


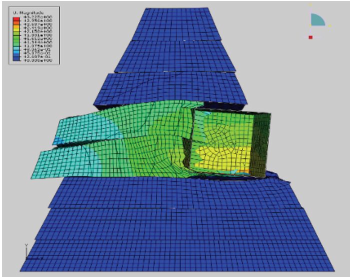
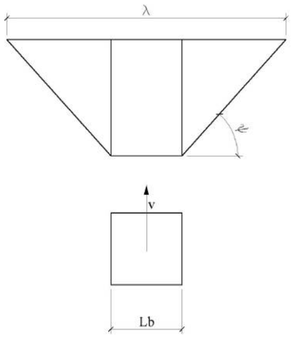


Fig. 1 *Left*: simplified cross section of the effect of the rock impact against the embankment: ξ = sliding of the reinforced layer at the downslope side, δ = penetration of the block into the structure at the upslope side. *Right*: contours plot of the numerical analysis (Ronco et al., 2009 and Oggeri et al., 2009).



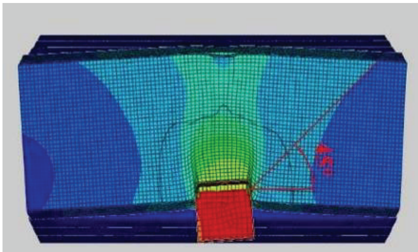


Fig. 2 *Left*: simplified plan view of the diffusion area into the embankment done with the Green Terramesh after the rockfall impact. *Right*: contours plot of the area involved in the impact (Ronco et al., 2009 and Oggeri et al., 2009).

The embankment must be sized such as to avoid the collapse (Ultimate Limit State) or the excessive downslope displacement (Serviceability Limit State). The first condition is satisfied when the block B (fig. 2) does not collapse because of displacement of the block A; the second condition (SLS) is satisfied when the impact crater is repairable and the maximum valley side displacement is acceptable (fig. 1). Obviously the embankment can be sized in order to admit several heavy impacts, that is till the block A displacement is next to the ULS displacement.

CONCLUSION

A new calculation approach, suitable for Officine Maccaferri embankment series, has been implemented. The calculation allows a quick dimensioning of these cost effective structures, which are generally used for energy levels upper than 3.5–5.0 MJ; their design procedure has been implemented as simple, pragmatic software, which summarizes a lot of analyses. The approach has been used for the design of embankments up to 50 MJ and higher than 15 m. The paper describes the theoretical bases of this new approach, and examines an example of rockfall embankment design.

REFERENCES

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