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CASE HISTORY

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COGNE ROCKFALL EMBANKMENT - Pt. 1

PONT LAVAL (COGNE), VALLE D'AOSTA

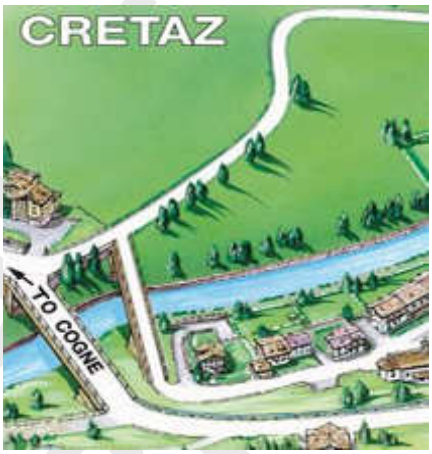
ROCKFALL PROTECTION

Product: Reinforced Soil Embankment System

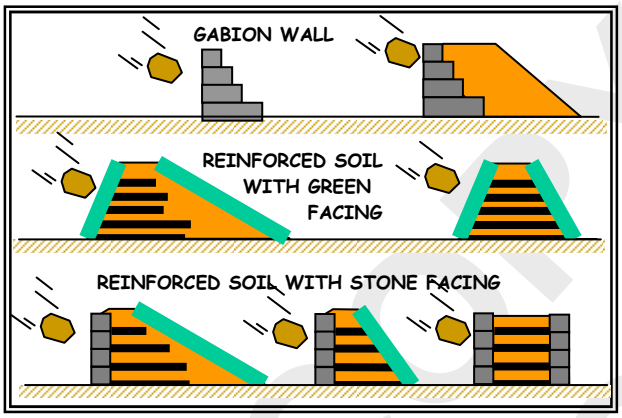
Introduction

The aim of this report is to indicate the design principles which have led to the solution described below for construction of a reinforced soil rockfall embankment - near the town of Cogne (Valle d'Aosta).

On the morning of 5 June 2007 a significant landslide of large blocks (of up to 80 m^3) occurred, which caused the closure of regional road M47 to Cogne. The landslide occurred from the rocky outcrop on the left-hand side near the village of Epinel (Pont Laval), just a few kilometres from the municipality of Cogne.



What is a Reinforced Soil Rockfall Embankment?



The need to ensure the safety of residential areas, infrastructures and any other day-to-day situations subject to the risk of landslides has resulted in the development of types of structures for protection against these phenomena, using technologies aimed at optimising the construction and maintenance costs.
Rockfall embankments consist of trapezoidal-shaped soil embankments, located in rolling terrain, to protect residential areas or infrastructures.

In the majority of cases the embankment is made of reinforced soil which has the advantage of keeping the embankment face almost vertical, with a consequent saving in construction material, reduction of overall size and improved efficiency for stopping rock blocks, as its avoids the rolling on the slope. It also provides a greater impact strength, thereby guaranteeing a greater energy absorption compared with a natural slope.

A trench may be formed in front of the embankment with the dual aim of intercepting the blocks prior to their impact against the embankment and collecting the mobilised blocks of rock.

The most frequent types of rockfall embankments are constructed from reinforced soil embankments, with steel or synthetic internal reinforcement, on which vegetation may grow where an aesthetic stone facing is not used.

The Pont Laval case

Following the landslide on 5/06/2007, and after the initial operations for removal of loose material using explosives, the unstable situation made further safety and protective measures necessary. The regional technical department of Servizio Sistemazioni Idrauliche e Dissesti di Versante, in collaboration with Maccaferri S.p.A., prepared the design for construction of two reinforced soil rockfall embankments based on the Maccaferri Green Terramesh system. The first 291m long and 11.5m high and the second 50 metres long and 11.5m high, to be located on the site of the Pont Laval municipal quarry. The construction time for the embankments was 4 months and the total cost for the works was c. €2.6 million. In 2009 a third embankment was built, 80m long and 11.5m high.

Fig 1. One of the rock masses that fell onto the road

Fig 2. The post-situation, viewed from above

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Design of a Reinforced Soil Rockfall Embankment

A rockfall embankment is designed in various phases which must analyse the kinematics of the block, the impact of the block on the embankment and the stability of the embankment itself and the global stability of the cut slope. With regard to the mechanism of the design block, it is necessary to identify its volume, the characteristics of the trajectory followed and the kinematic parameters of the block at impact.

With regard to the characteristics of the rock from which the block is formed, the type of soil it strikes and the irregularity of the ground surface, the impact may occur with various directions, heights and energies. At the moment of impact, the block of rock develops a force against the embankment which generates a penetration.

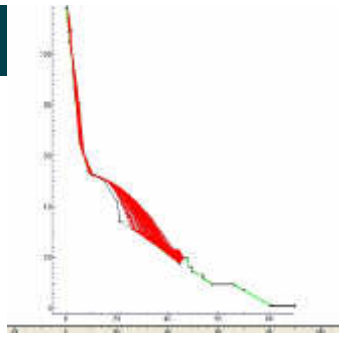

Fig 3. Simulation of the trajectory of falling blocks

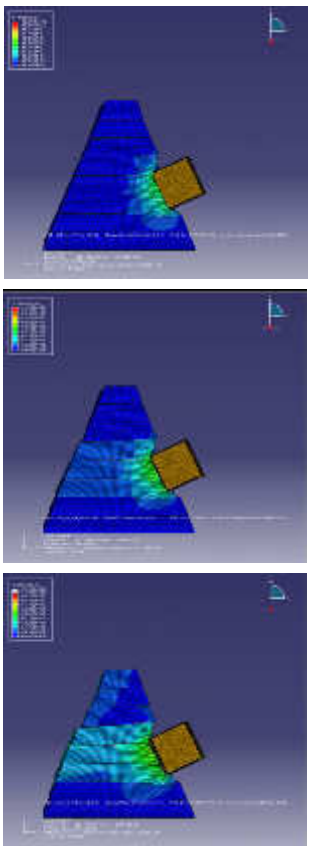

Fig 4. Simulation of the movements of the embankment body following

There are numerous empirical formulae in the literature (e.g. Kar, 1978) which permit an evaluation, in general with the assumption of an elastic-plastic behaviour of the material forming the embankment and a dynamic load that varies with time, of the value of the maximum impulsive force - from which it is possible to determine the penetration of the block into the embankment. However, these formulae have often proven to be un-realistic, so Polytechnico di Torino has developed the numerical analysis of rockfall embankments reinforced with DT mesh on the basis of laboratory test results (e.g. behaviour of the reinforcement material-soil analysis) and back analysis of real events.

Numerical modelling is essential for the correct evaluation of the behaviour of this type of structure when subjected to impacts, i.e. impulse type forces. The embankment may not be considered to be a continuous or isotropic body, and under dynamic conditions it is subject to large deformations and plasticization of the elements, so it falls outside the formulae of construction science and conventional mechanics.

In particular, by making reference to the full-scale tests carried out in the past (by Polytecnico di Torino), it was noticed that a reinforced soil embankment subject to the impact of a rock block dissipates the kinetic energy with two distinct phenomena: the compaction and plasticization of the soil in the area of impact, with the consequent formation of the imprint on the embankment face, and the subsequent movement in a downstream direction of the paths involved in the impact in question.

An analysis was carried out with the numerical modelling of the Terramesh type embankment structure made with Officine Maccaferri Reinforced Soil Embankment System materials. The numerical modelling was developed using the ABAQUS/Explicit© finite elements software package in the dynamic field.

An analysis of the modelling results has shown how reinforced soil embankments support impacts with an energy of much higher than 5000 kJ, keeping the deformation of the downstream facing decidedly low.

Following the definition of the extent of the penetration and the impact force of the block on the structure, the embankment stability must be checked to ensure that all the curvilinear surfaces which represent possible sliding mechanisms, through the structural embankment (internal check) (Fig. 5). Additionally the stability of the surrounding soil (global check) must be checked (Fig. 6) and verified to have a safety factor which is greater than a value set by the designer, in accordance with the provisions of the current standards. Any other pertinent conditions must also be checked according to site requirements.

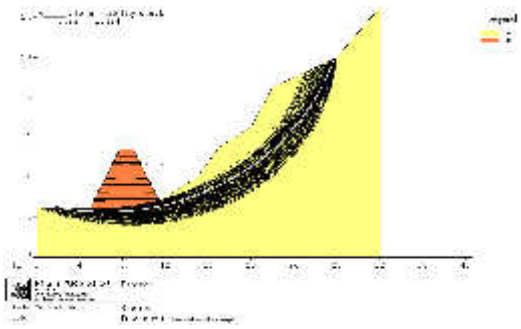

Fig 6. Example of global stability checks for a reinforced soil embankment. The check may be performed with limit state methods (MacStaRS 2000 - www.maccaferri.com)

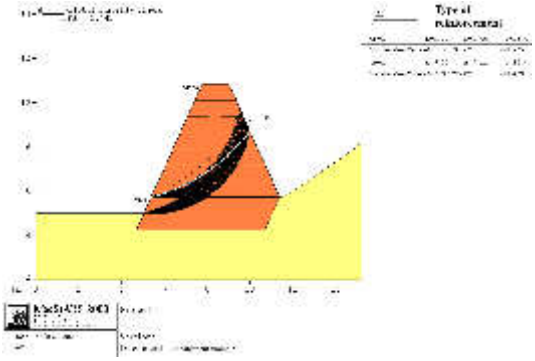

Fig 5. Example of stability check inside embankment body, for the reinforcements of a reinforced soil embankment The interaction between reinforcement and backfill soil is checked in this analysis (MacStaRS 2000 - www.maccaferri.com)

Construction of Pont Laval Reinforced Soil Rockfall Embankment

Fig 7. The embankment under construction

The construction of a rockfall embankment is subdivided into successive phases which guarantee the satisfactory outcome and service life of the structure. Following identification of the best location for the embankment - both vertically and horizontally - by an analysis of the trajectory of the blocks, the foundation layer must be prepared in order to guarantee good load-bearing and stability characteristics.

The reinforcement elements are then installed, taking care to place approx. 30 cm thickness of seeded top soil next to the facing [factory lined with biomat], to favour the subsequent growth of vegetation.

The structural embankment fill consisted of good quality soil (granular and specifically selected according to the engineer's specification) with a high drainage capacity and a high internal angle of friction and, above all, it must maintain its characteristics unaltered over time.

The Cogne embankment fill was placed and compacted in successive layers with thicknesses of not more than 30-35 cm, using traditional plant (rollers, vibrating plates, etc.). After the embankment was completed the outer face was hydroseeded to favour the growth of vegetation (pre-seeded soil can be a better method).

In the specific case of Pont Laval the Green Terramesh system was used, which consists of pre-assembled units where the reinforcement is plastic coated double-twist wire mesh (mesh type 8x10, wire diameter 2.7i.-3.7e.), whilst the outer face consists of stiffening weldmesh and a coconut biomat (ref. detail, Fig. 10). Due to the harsh nature of the impacts, height of the structure, and the repeated impacts expected at this site the embankment fill was additionally internally reinforced using high specification Paragrid geogrids at 3m centres.

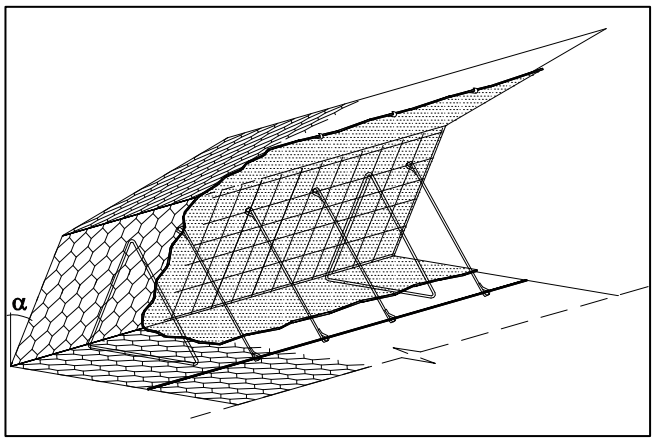

Fig 10. Diagram of the characteristics of the Terramesh system element

Fig 8. Compaction of lifts of fill material

Fig 9. Embankment construction, view from downstream (SR47)

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The Pont Laval Reinforced Soil Rockfall Embankment—Post Completion

Fig 11. Lateral view of upstream embankment after completion of construction phase works.

Fig 12. View of the two embankments three months after construction: the grassing over and aesthetically successful insertion into the surrounding environment can clearly be seen.

The July 2008 landslide on the Pont di Laval Reinforced Soil Rockfall Embankment

Fig 13. General view of the two embankments in July 2008 after the collapse of a cascade of blocks (>10,000kg)

Fig 14. Close-ups of the blocks which struck the upstream embankment

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