Optimization of a rockfall protection embankment above the A43 highway

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The A43 highway between Lyon and Chambery crosses the Pre-Alps by 2 tunnels. The west end of the Dullin tunnel is located at the base of a 200-m-high limestone cliff. The tunnel is extended by 20-to-30-m-long galleries, supporting a service road (figures 1 and 2). The highway administrator wanted to protect the highway against rockfall and, if possible, the service road. GEOLITHE was the project manager of these works.
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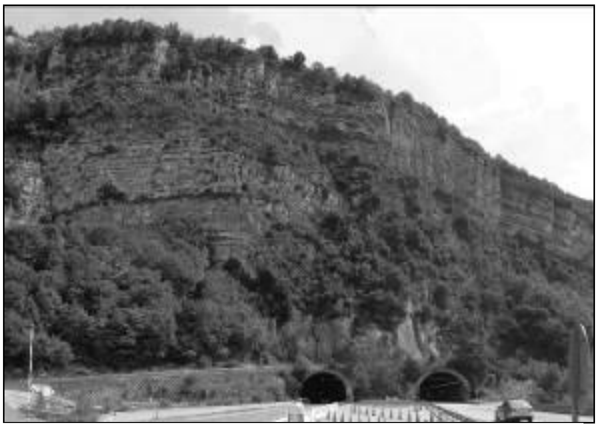

Figure 1: Sight of the cliff from the highway

Figure 2: Sight of the highway from the top of the cliff

1 DISCUSSION ABOUT THE DIFFERENT SOLUTIONS

Rockfall simulations revealed that, at the position of the service road, the trajectories are very high: up to 25 m. As a consequence, it was not possible to stop all the blocks only with rockfalls barriers or embankments.
A first solution was to build deflectors with high resistance wire mesh, and to intercept blocks at the foot of the cliff with an embankment. This solution, which would have covered the cliff, was unthinkable for environmental reasons.
It was so decided, in agreement with the highway administrator, to anchor the more unstable rock blocks above 1 m^3 volume, and to build an embankment at the foot of the cliff. This embankment will certainly be lobbed, because some trajectories are too high to be intercepted. As a consequence, the outside galleries can be damaged by a rockfall. The aim of the design was then to optimize the embankment in order to intercept as many blocks as possible.

2 OPTMIZATION DURING THE DESIGN

A first design was a 9-m-high embankment, situated at the end of the galleries (figure 3). It allowed to stop about 99.5% of less than 1 m^3 rockfalls.
In order to match the resistance of the embankment and the kinetic energy of rockfalls, it was planned with a thickness of 4m, and had to be made with gabion cages ligatured one by one, filled with a crushed quarry stone.

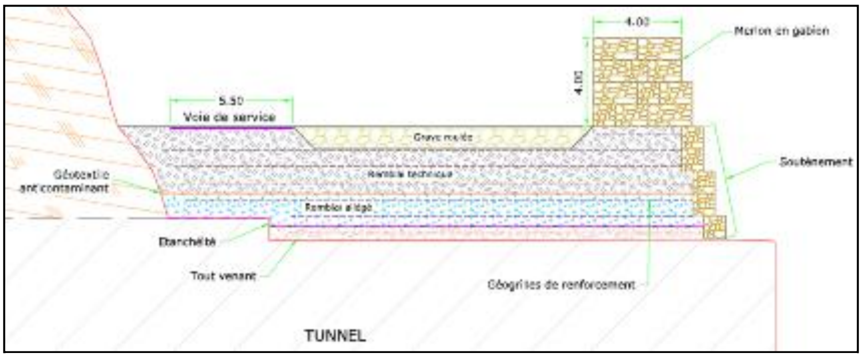

Figure 3: 9-m-height embankment with multi-layer filling

In order to limit the dynamic load on the gallery structure due to the rockfalls impacts, a multi-layer filling was imagined, with rolled gravel on top, reinforced soil with geotextile layers to spread dynamic strains, and lightweight material to reduce static strains. The service road was poorly protected, but it was not the main aim of the administrator, because of the low traffic on this road.
This solution was finally not feasible, because the foundations of the galleries could not support the weight of the whole structure.

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It was so decided to build a gabion embankment, as high as possible (4 m), at the end of the galleries too. It allows to stop about 99% of less than 1 m^3 rockfalls. The service road has been located just behind the embankment, in order to be less reached by small rockfalls (probably the most frequent). In order to limit the dynamic load on the gallery structure due to the rockfalls impacts, a 2-m-high filling of rolled gravel was planned on the galleries structure, between the cliff and the service road. See figure 4.

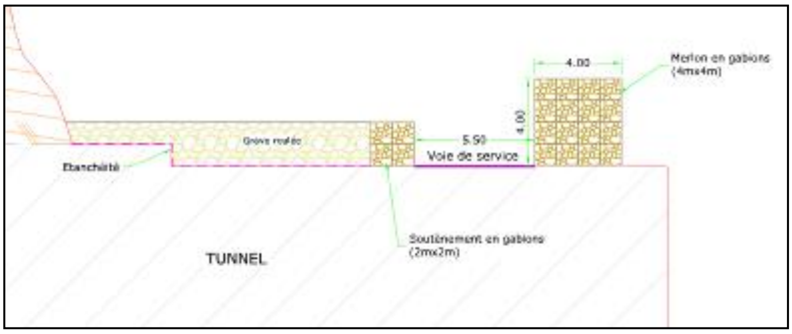

Figure 4: 4-m-height embankment

3 OPTMIZATION DURING THE BUILDING

During the construction, the working company Forézienne d'Entreprise (Eiffage) wanted to limit the gabion volume with a sandwich structure composed of two gabion walls around a crushed material. Such structures are less resistant than a structure entirely composed of gabions cages. Indeed, the structure is less intertwined and the lateral spread of dynamic strains is less significant. A reinforcement of the structure had to be imagined in order that the embankment can be as efficient as the designed solution.
First, the structure stability has to be ensured by horizontal geogrid layers added between the two gabion walls.
Then, a vertical welded mesh, made of 9-mm-diameter bars, is positioned just behind the cliff-side gabion wall, in order to constitute a rigid and resistant layer which will be able to spread the strains due to an impact. In order to allow the implementation of the geogrids, the vertical continuity of this reinforcement is ensured by vertical metallic bars.

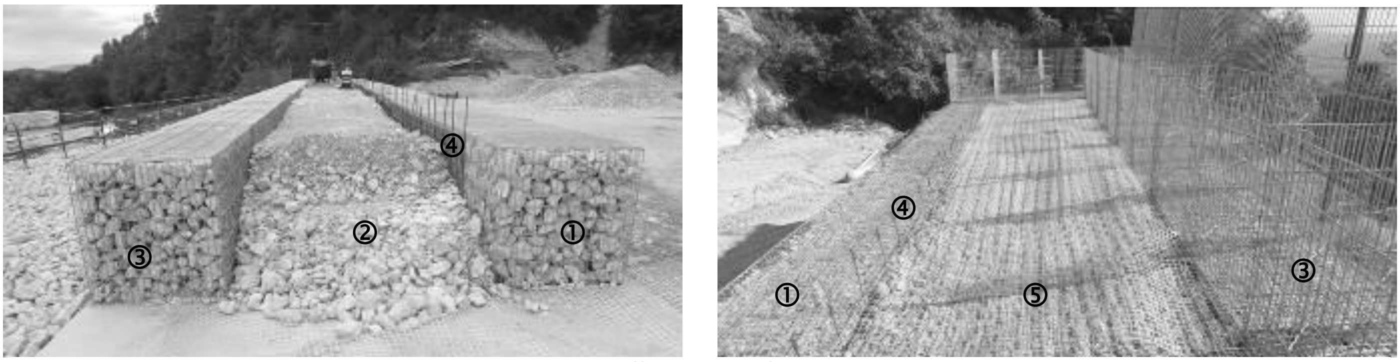

Figure 5: Different sights of the building
① gabion cages on cliff side - ② crushed material - ③ gabion cages on highway side - ④ reinforcement structure made of vertical welded mesh) - ⑤ geogrid

CONCLUSION

The different optimizations carried out during the design and during the building resulted in an embankment which fully met the expectation of the highway administrator, realised in a short time and at a limited cost.

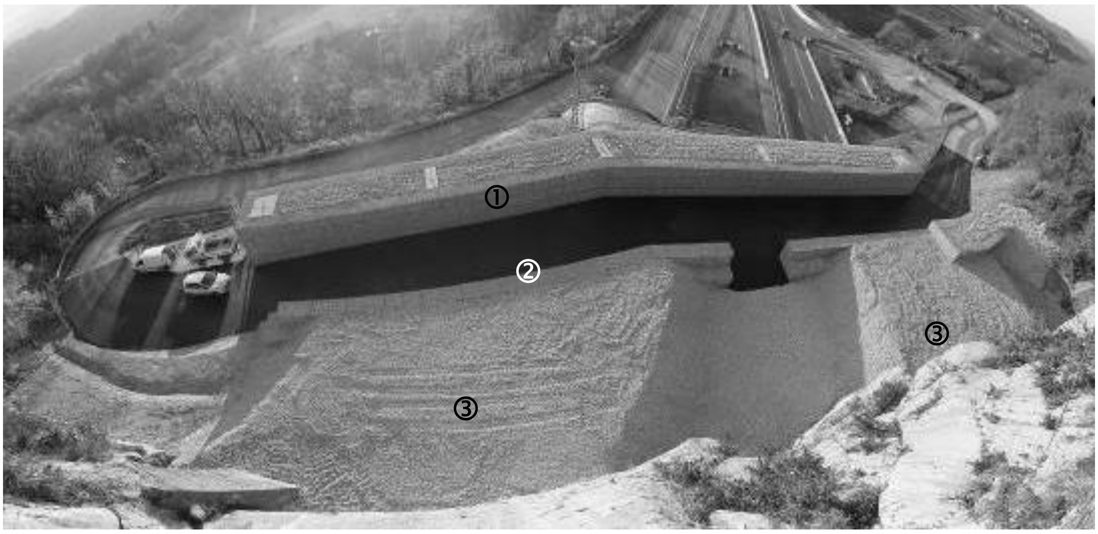

Figure 6: Sights of the finished embankment
① principal embankment - ② service road - ③ rolled gravel on galleries structure)