High energy impacts for assessing the Bloc Armé® technology as rockfall protection

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Keywords: rockfall, protective structure, impact, real-scale experiments

ABSTRACT IN ENGLISH:
This article presents high-energy impact tests on two different real-scale rockfall protection structures employing the *Bloc Armé*® technology. The aim is to emphasize the potential of this recently developed technique while defining the impact strength of the tested alternatives.

ABSTRACT IN FRENCH:
Cet article présente des essais d'impact réalisés à échelle réelle sur deux variantes d'ouvrages utilisant la technologie *Bloc Armé*®. L'objectif de cette campagne était d'illustrer le potentiel de cette technique et d'évaluer la résistance à l'impact des différentes alternatives considérées.

1 INTRODUCTION

Rockfall are frequent in mountainous areas. These events may damage infrastructures and injure or kill people. The growing urbanization and tourism development in areas prone to rockfall, strengthen the need for optimized protection structures with respect to constraints in particular related to the structure footprint, construction time and ease of repair. In this context, the *Bloc Armé*® technology was developed by Géolithe and Géolithe Innov. The technology has already been tested at small-scale (A. Furet et al., 2020) and at real-scale at low energy. This communication deals with the high energy impact response of two different alternatives using this technology, differing by their geometry, design and impact strength. The technology was first tested alone in a specific geometry wall and then coupled with gabion facing.

2 EXPERIMENTAL METHODS

2.1 Tested structures and impacts tests

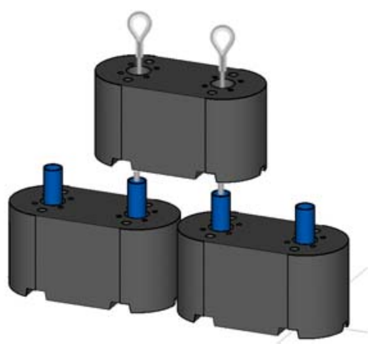

Figure 1: Bloc Armé® concept

The experiments consisted in sub-horizontal impacts by ETAG27-type reinforced concrete projectiles 2500 or 4800 kg in mass with different kinetic energies. These experiments were performed on the pendulum testing facility of the Université Gustave Eiffel test site (Montagnole, France).
The *Bloc Armé* technology consists of reinforced concrete blocks and a set of metallic reinforcement elements (Figure 1) to form articulated, self-standing and heavy rockfall protection structures. Tubes and cables are introduced vertically through holes in the staggered blocks. Vertical cables are fixed at base using bars and at the summit using a cable (Figure 2) to form a unified reinforcement mesh able to distribute the forces. Gaps between elements allow relative displacements between blocks and give the wall a certain deformability.

The modularity of the technology allows its use in different ways. Two different walls 3.2 m in height were submitted to centered impacts at a height of 1.7 m:

- (1) *Bloc Armé* zig-zag wall (Figure 2a), 500 kJ and 1000 kJ impacts in the concavity
- (2) *Bloc Armé* zig-zag wall with a gabion facing (Figure 2b), 2000 kJ impacts in the concavity

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2.2 Measurement

In order to evaluate the displacements of the walls, accelerometers and wire extensometers were fixed to the blocks at different positions at the back of the wall. High-speed cameras recorded images at 1000 frames per second in two perpendicular directions. In addition, a topographic survey was conducted based on photogrammetric methods to measure the final deformation of the walls.

3 RESULTS

Impacts on the walls made of *Bloc Armé* alone demonstrated a good capacity of the structure to distribute loads. The wall length experiencing sliding was as large as 8 m and 11 m with a maximal displacement of 1 m and 1.45 m during the 500 kJ and 1000 kJ-impacts respectively. The lateral transfer of loads favors energy dissipation by friction and limits the maximal displacement. The impacted blocks fractured. However, we note that complete fracturing and opening of blocks were prevented thanks to the significant reinforcement of the blocks concrete (Figure 2a).
For a 2000 kJ impact, gabion cells (crushed gravel in wire mesh cells) were placed as facing. With this facing, the maximal displacement reaches 1.5m and the structure length experiencing sliding is 11m.Thanks to the gabion facing, no block fractured. Gabions facing improves the structure impact strength by damping the impact force, dissipating energy and distributing loads (Lambert et al, 2020). At this stage, the importance of each mode of action and the specific phenomena are neither precisely identified nor quantified.

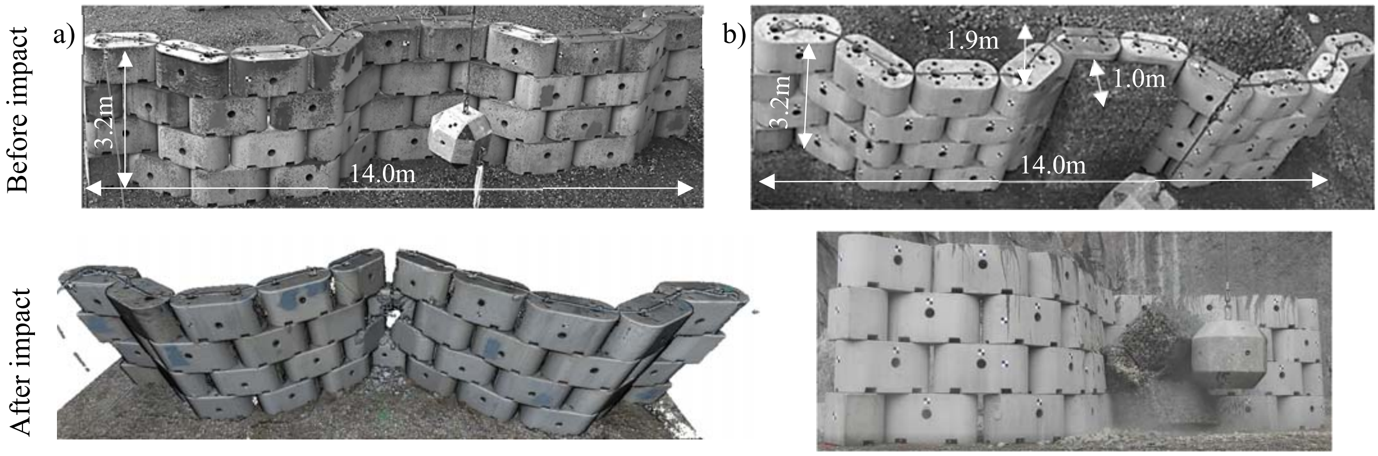

Figure 2: Tested structures before and after impact, *Bloc Armé* wall a) alone at 1000 kJ b) with gabion facing at 2000 kJ

CONCLUSIONS

The impact tests results show a good capacity of *Bloc Armé* walls to resist high energy impacts. The reinforcement elements distribute loads laterally. The wall resists and the maximum displacement remains acceptable. The campaign proves that complex geometries can be built and that the technology can be easily combined with a granular facing to increase the structure capacity up to 2000 kJ. As a perspective, these first results and measurements constitute interesting data to be analyzed to understand the effect of the facing on the dynamic behavior of the structure.

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