Assessment of the robustness of a numerical model of Bloc Armé® rockfall protection walls considering high energies impacts on real-scale structures

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Agathe FURET[1], Jean-Philippe JARRIN[2], Stéphane LAMBERT[3], Pascal VILLARD[4]

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ABSTRACT IN ENGLISH:
With the aim of proposing a rockfall protection structure responding to new needs, Géolithe and Géolithe Innov have developed the Bloc Armé® technology to build modular structures optimized regarding footprint, time construction and reparability. In this purpose, a 3D numerical model of the structure was developed and revealed promising in terms of structure response prediction while providing insights into dominating energy dissipative mechanisms. This communication deals with the evaluation of the robustness of this modelled when simulating high energy impacts on real-scale *Bloc Armé* structures, based on the comparison with experimental results.

ABSTRACT IN FRENCH:
Pour répondre aux nouveaux besoins de structure de protection contre les chutes de blocs rocheux, Géolithe et Géolithe Innov ont développé la technologie Bloc Armé®, permettant de construire des structures modulaires optimisées en termes d'emprise au sol, de temps de construction et de réparabilité. Un modèle numérique en 3D de la structure a montré une bonne capacité à reproduire le comportement de la structure et a permis de mieux appréhender la dissipation d'énergie en son sein. Cette communication s'intéresse à la robustesse du modèle numérique en considérant des impacts à haute énergie sur des structures à échelle réelle, et s'appuie sur la comparaison entre les déplacements du mur issus des simulations et ceux mesurés expérimentalement.

1 STRUCTURE AND MODEL DESCRIPTION

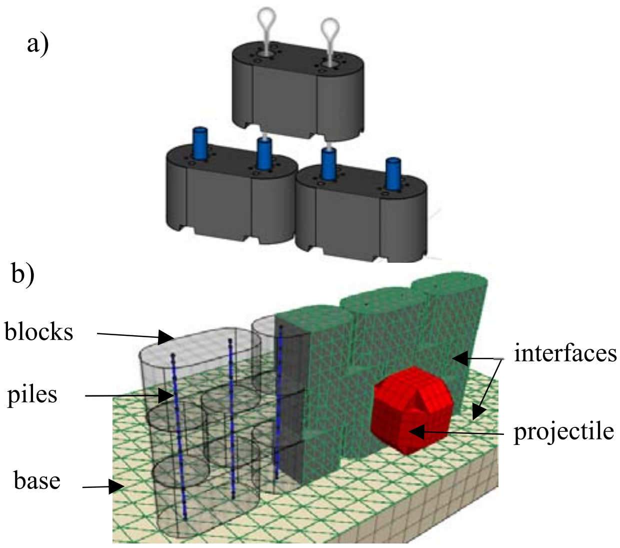

Figure 1: a) Real structure concept b) numerical model

The *Bloc Armé* technology consists of reinforced concrete blocks and a set of metallic reinforcement elements (Figure 1a) forming 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 and top of the wall to form a unified reinforcement mesh able to distribute the forces. Gaps between elements allow relative displacements between blocks and give to the wall a certain deformability.

The model (Figure 1b) was developed with *FLAC3D* (Itasca 2017). The concrete blocks are modelled by discrete blocks of continuum media stacked to form the wall, placed on a base. The Mohr-Coulomb constitutive model used for blocks elements allows to consider the energy dissipation by plasticization.

The metallic reinforcements (tubes and cables) are modelled thanks to *"piles"* elements existing in *FLAC3D.* These structural elements transmit forces from one block to the other, increasing the structure mass associated with the impact. The free space between the reinforcement elements and the blocks being a key parameter in the dynamic response of the wall, it is accounting for in the simulation via a specific reinforcement element-block interaction model: the reinforcement element is free to move before it is blocked when it equals the gap existing between elements. In addition, an authorized displacement of 5cm is introduce at top of the wall to consider the slack at top fixation of the cables.
"Interfaces" are used to manage rigids and frictional contacts between the concrete blocks, the base and the projectile, allowing sliding, detachment and force transfers. The friction angle at the block/block and block/base interfaces have

[1] FURET Agathe, Géolithe, Crolles, France (FR), agathe.furet@geolithe.com
[2] JARRIN Jean-Philippe, Géolithe, Crolles, France (FR), jp.jarrin@geolithe.com
[3] LAMBERT Stéphane, Univ. Grenoble Alpes, INRAE, ETNA, Grenoble, stephane.lambert@inrae.fr
[4] VILLARD Pascal, Univ. Grenoble Alpes, 3SR, Grenoble, France (FR), pascal.villard@univ-grenoble-alpes.fr

been determined by static sliding tests and reduced by 25% for taking into account the dynamic nature of the solicitation. In accordance with Itasca's recommendation, the interfaces normal and tangential stiffness are given high values compared to equivalent stiffness of the neighboring zones, in order to limit the influence of the elastic strain of the interfaces.

2 IMPACT SIMULATIONS ON STRUCTURES

Previous simulations demonstrated the model's ability to reproduce the dynamic behavior of walls made of *Bloc Armé*. This work (Furet, 2020) was limited to small scales and to small size walls impacted at moderate energy (<125 kJ). Recent high energy impact tests, conducted on real scale walls, allow to verify the robustness of the numerical model.

Two impacts (500 kJ, mass:2,5t, velocity:20 m/s and 1000 kJ, mass:2,5t, velocity:28,4 m/s) are simulated in a realistic way, by throwing the projectile on the wall with an initial controlled velocity. The conditions are similar to experimental conditions regarding the projectile geometry, mass, velocity magnitude and pre-impact trajectory.
Very similar trends and values are observed between the simulations and the experiments (Figure 2a). These concerns the wall unfolding, the sliding of a significant length of the wall, the maximum displacement (Table 1) and kinematic. The displacement of the top of the wall shows that the model is efficient to replicate the dynamic behaviour, with a maximal displacement reached after 450 ms for a 500 kJ impact (Figure 2b). The main difference concerns the reversible displacement observed at top of the wall, which is partially attributed to the simplification concerning the modelling of tubes displacement in the blocks.

	500 kJ		1000 kJ	
	Exp	Num	Exp	Num
Maximal displacement (m)	0.90	0.96	1.40	1.25
Displaced length (m)	8	8	11	11

Table 1: Experimental and numerical result

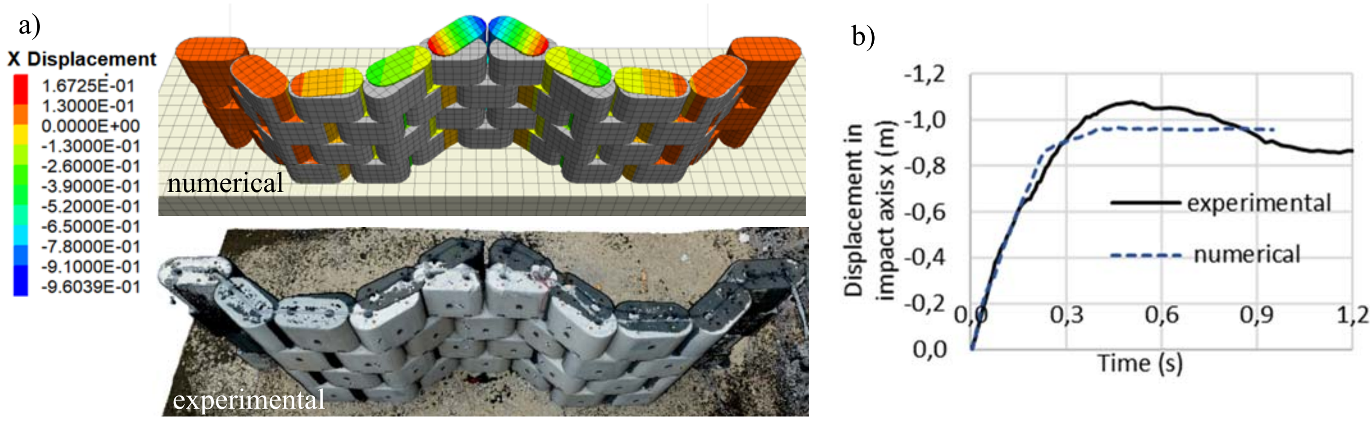

Figure 2: Experimental and numerical comparison for 500 kJ impact a) wall final deformation b) Displacement of the top of the wall

CONCLUSION

The numerical model reveals efficient in reproducing displacement of real scale walls under high energy impacts. These results are promising in view of using the model as a design tool for rockfall protection structures. The numerical model represents an interesting tool to realize parametric studies aiming to identify the influent parameters. The numerical modelling of *Bloc Armé* walls coupled with gabions facing also impacted at high energy constitute an interesting perspective.

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