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# Monitoring the reinforcement and slow-dynamics response of a rock column in the limestone Vercors massif, western pre-alps, France

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We use ambient vibrations to monitor the natural resonance frequencies (normal modes) of a limestone rock column during bolting works [1], the efficacy of which is usually difficult to estimate. The test site is a 760 m3 unstable compartment located in the Bourne valley (Vercors, France). The rock column's resonance frequencies ($f_x$) are identified, corrected for reversible thermal effects and monitored over two months. We observe clear increases in $f_x$ up to $\sim 17\%$ resulting from the additional stiffness provided by the steel rock bolts. Numerical modeling helped to confirm that the rebar elements were grouted on both sides of the fracture. The major column's resonance features, such as the resonance frequencies and mode shapes, are successfully simulated, including their evolution with bolting. The amount of $f_x$ increase depends on the mode considered, likely controlled by bolt location in comparison with the modal shape, and the geometry of the rear cracks.

Before the bolting operation, we also evidence a slow-dynamic response of the rock column after brief mechanical solicitations: during and right after drilling the rock, we observe an immediate frequency drop and a slow recovery (some minutes to some hours) back to the initial natural frequency value. This appears to be a large-scale analog of slow-dynamics experiments [2,3] conducted in the laboratory, explained by reversible non-linearities of the mechanical parameters of the rock, most probably related to the evolution of grain contacts inside the rock and/or along the fracture delimiting the column.

This study confirms the potential of ambient vibrations to provide global in-depth information on the stability evolution of rock compartments, with versatile applications for monitoring potential rockfalls or reinforcement works.

[1] P. Bottelin, L. Baillet, E. Larose, D. Jongmans, D. Hantz, O. Brenguier, H. Cadet, A. Helmstetter : *Monitoring rock reinforcement with ambient vibrations : La Bourne case study (Vercors, France)*, Engineering Geology **226** 136-145 (2017).

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