Stability of fragmented and blocky solids

Igor Shufrin¹, Elena Pasternak², and Arcady Dyskin³,⁴

¹Department of Structural Engineering, Faculty of Engineering Sciences, Ben-Gurion University of the Negev, Israel (shufrin@bgu.ac.il)
²Department of Mechanical Engineering, The University of Western Australia, Australia (elena.pasternak@uwa.edu.au)
³Department of Civil, Environmental and Mining Engineering, The University of Western Australia, Australia (arcady.dyskin@uwa.edu.au)
⁴Beijing Research Center for Engineering Structures and New Materials, Beijing University of Civil Engineering and Architecture (BUCEA), China (arcady.dyskin@uwa.edu.au)

Fragmented geomaterials are discontinuous solids assembled of blocks, which are not joined together by any binder. The integrity of these solids is provided by interlocking of the interfaces between the fragments and compression applied at the boundary of the assembly. The main distinctive feature of these solids is the ability of separate fragments to move and rotate independently within the geometric constraints imposed by the neighbouring elements. Under application of external loads the fragments partially lose contact – the blocks get detached in a part of their contact area – that reduces the stiffness of entire blocky structure. The compression applied at the boundaries of the structure restores these contacts and brings shifted blocks back to their place. At the same time, this external compression can cause instability of the assembly, in particular when applied over heavily detached interfaces. This instability mechanism is highly nonlinear due to the rotation of the fragments that produce elbowing effect and increases the compression.

In order to assess the stability of fragmented solids, we carried out a series of experiments on the fragmented beams assembled of prismatic blocks and topologically interlocked osteomorphic blocks. The beams were axially prestressed and loaded in the transverse direction. We observed that the blocky beams can exhibit negative stiffness in the certain testing regimes. The block rotations observed during bending decrease the bending stiffness of the beam through the partial detachments between the fragments, while increasing the axial force due to the elbowing effect, which allows the beam to sustain additional bending deformations without increase in the external loading. This apparent negative stiffness is controlled by the combination of the prestress levels and rigidity of the axial beam constraints. We also verified these results through finite element simulations and analytical modelling.

Acknowledgements: This research was supported by the ISRAEL SCIENCE FOUNDATION (grant No. 1345/19).