Analysis of 3D no–tension masonry–like walls

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The no–tension model can be used in the analysis of structures made of brittle materials to obtain a preliminary description of their mechanical behavior. The model is based on the assumption that the stress tensor is negative semi–definite, and depends linearly upon elastic strains, see e.g. [1]. Notwithstanding the simplicity of this model, serious numerical problems are found even in the analysis of elementary cases. To overcome this kind of instabilities, some robust numerical approaches have been proposed in the last decades. Most of them resort to incremental strategies of non–linear finite element analysis, see e.g. [2, 3]. Alternatively, the no–tension assumption can be handled through the minimization of a suitable form of the elastic strain energy. A numerical method was proposed in [4] that seeks the equilibrium of two-dimensional no–tension bodies through the minimization of the potential energy. Following this approach an equivalent optimization problem was formulated in [5] and implemented in [6] to investigate the in–plane and out–of–plane behavior of masonry walls through simplified 2D models.

Assuming masonry to behave as a linear elastic no–tension material, a numerical method is introduced to analyze 3D masonry structural elements, with special attention to masonry walls. Masonry is replaced by an equivalent orthotropic material with spatially varying elastic properties. Using an interpolation typical of Topology Optimization, the stiffness of the equivalent material is given negligible values in any direction along which tensile stresses must be prevented. An energy-based optimization algorithm defines the distribution and the orientation of the equivalent material for a given load, so as to obtain a purely compressive state of stress throughout the element. A regular mesh of eight node finite elements is used to speed up the sensitivity analysis.

The capabilities of the approach in predicting no–tension stress solutions in masonry walls with openings of different shape is shown. The effect of settlements is investigated as well. The collapse load of walls subject to horizontal actions is predicted by running a sequence of independent analyses on the same discrete model, to investigate both their in–plane and out-of–plane behavior.

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