Topology optimization of masonry blocks with enhanced thermomechanical performances

Matteo Bruggi[1], Carlo Cinquini[2], Alberto Taliercio[1]

[1]Dept. of Civil and Environmental Engineering, Politecnico di Milano, Italy
[2]Dept. of Civil Engineering and Architecture, University of Pavia, Italy

Abstract

One of the primary goals in the field of modern construction is to design buildings with high thermal performances. This is dictated primarily by the need of reducing energy consumption in the exploitation of the building, because of the progressive decrease in available energy sources and the need of limiting the emissions of pollutants. This can be achieved e.g. acting on the exposure or the shape of the building, optimizing the technological systems, using large transparent walls to increase lighting and passive heating, as well as materials and construction elements that minimize the heat flow across the external walls of the building.

In this work, attention is focused on the optimal design of the shape of masonry (or concrete) blocks in order to minimize their thermal transmittance (i.e., to maximize their thermal resistance). The `thermal transmittance' (usually denoted by *U*) of any wall is the heat flow per square meter, divided by the difference in temperature between the faces of the wall itself.

Assuming the heat flux to be uniform across the wall surfaces, topology optimization is employed to define the layout of the block section. Constraints on the block stiffness are also prescribed. The presence of holes of given shape in any prescribed position and other technological constraints can be easily embodied in the optimization procedure. The effect of the design constraints on the optimal layout of the blocks is investigated. The thermal efficiency of the optimized units is also compared with that of commercially available blocks.

Existing approaches dealing with the optimal design for thermal insulation resort to formulations of topology optimization that are based on the heat equation. Structural performances of the building envelope are generally neglected, see e.g. [1-4]. The proposed approach consists in an original formulation that may handle the design of masonry blocks, dealing with the simultaneous optimization of the thermal and mechanical performances of the blocks. Non-trivial optimal block layouts can be achieved, depending on the design constraints. The inclusion of stiffness/strength requirements in the minimization of the thermal transmittance remarkably affect the optimal design along with its performances.

Key words: block masonry, thermal conductivity, topology optimization.

[1]Buttazzo G., 1988. An optimization problem for thin insulating layers around a conducting medium. In: Boundary control and boundary variations. Lecture notes in computer science Vol. 100. Berlin: Springer-Verlag, 91–95.

[2]Li Q. et al., 2004. Evolutionary topology optimization for temperature reduction of heat conducting fields. International Journal of Heat and Mass Transfer, 47 (23), 5071–5083.

[3]Munoz E., Allaire G. and Bendsøe M.P., 2007. On two formulations of an optimal insulation problem. Structural and Multidisciplinary Optimization, 33 (4–5), 363–373.

[4]Bruggi M., Cinquini C., 2011. Topology optimization for thermal insulation: an application to building engineering. Engineering Optimization, 43(11), 1223-1242.