Airy-based form-finding process for purely compressed masonry cross vaults under combined vertical and horizontal loading

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Abstract

Unreinforced masonry structures throughout the world are often condemned or subjected to inappropriate and potentially damaging 'strengthening' interventions in the aftermath of seismic events. This is due to an inability to readily estimate their horizontal force capacity – a knowledge gap which can also be a barrier to new masonry construction, particularly of structurally efficient shells and vaults. After a certain load capacity threshold, hinge formation leads to the activation of rocking-like mechanisms in these structures, requiring a dynamic analysis dependent on characteristics of the earthquake. However, this activation threshold and the structural behaviour before it is reached are primarily dictated by geometry. This paper presents a strategy for calculating this horizontal load threshold for compression-only shells, with applications in the assessment of historic constructions and form finding of new designs. The method utilises Membrane Equilibrium Analysis (MEA), based on the Safe Theorem of Limit Analysis and Heyman's assumptions for masonry-like, no-tension materials. By formulating horizontal equilibrium as a set of parametric equations and constraining the solution for the stress potential to be concave, this method obtains the maximum value of the horizontal load multiplier for which equilibrium remains satisfied by a given shell geometry. Challenges of discontinuity in the structural form are then tackled, through application of the method to the analysis of cross vaults.

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