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Fast and reliable non-linear heterogeneous FE approach for the analysis of FRP-reinforced masonry arches

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Abstract

A simple and reliable finite element model is presented, specifically conceived for the analysis of FRP-reinforced masonry arches. The approach proposed relies on the reduction of mortar joints to interfaces exhibiting a non-linear holonomic behavior under mixed mode conditions, whilst bricks are discretized by means of four-noded elements remaining linearly elastic up to failure. The FRP reinforcements glued at the intrados or at the extrados are modeled by means of truss bar 2-node elements connecting contiguous nodes of the discretized support, with elastic-brittle behavior in tension and no strength in compression. The predictions provided by the plane stress model, exploiting also the Italian CNR Recommendations for the engineering practice, are validated against some recent experimental results concerning circular and parabolic masonry arches reinforced by glass and carbon FRP.

1. Introduction

The mechanical assessment of masonry arches beyond elasticity is a classic topic in computational mechanics, that however so far has been tackled almost exclusively in the framework of limit analysis [1]-[7]. As a matter of fact, limit analysis in the form of both lower and upper bound theorems allows for a direct estimation of the load carrying capacity of the structure without expensive step-by-step simulations. Especially in the study of masonry arches with plastic hinges, to which the assumption of no tension materials well adapts, limit analysis admits also graphical solutions: in those cases both thrust lines (static approach) and the four hinges mechanism (kinematic approach) can be provided. There are however some major limitations in the application of conventional limit analysis, intrinsically linked to its basic hypotheses, as for instance the perfectly plastic behavior of the material (damage or post-peak softening response are therefore