FINITE ELEMENT MODEL FOR FRP-FROM-MASONRY DELAMINATION: THREE-DIMENSIONAL EFFECTS AND INTERFACE TRACTION ASSESSMENT

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ABSTRACT

In recent years, FRP composites have been widely used in the field of masonry structures, especially to increase the in-plane shear resistance or to provide additional out-of-plane strength in a non-invasive way. It is therefore of significant interest to develop numerical tools apt to predict the nonlinear response of FRP-reinforced structures up to failure.

Within a finite element approach, large-scale nonlinear analyses based on micro-modeling (i.e. with a distinct representation of each brick, mortar joints and FRP strip) exhibit in general a prohibitive cost. To circumvent this limitation, a 1D interface law (in mode II) is usually adopted to describe the interaction between the FRP strip and the underlying support, in a linear background. The above relationship is formulated in terms of shear tractions acting along the interface and tangential relative displacement (“slip”) between the two adherent surfaces, i.e. the reinforcement and the masonry.

As experimental evidences have shown, during delamination tests, damage diffuses extensively inside bricks and mortar [1], being the adhesive several times more resistant, with three dimensional [2]-[5] effects always evident. Such a 3D behavior is dominated by the mutual width of the strip and the masonry structural element where the FRP is glued. All these aspects make the prediction of both ductility and load carrying capacity of this typology of external reinforcement a very difficult task. While in [1] a 2D plane strain approach was proposed to strongly reduce the computational effort required to perform parameter analyses on a masonry pillar subjected to delamination, here recourse is made to a fully three-dimensional FE model, following the model proposed in [2]. A heterogeneous approach is adopted, suitable to predict accurately the actual failure mechanisms. A squat masonry pillar is considered, constituted by three Italian bricks interspersed by two mortar joints and reinforced with an external FRP sheet. It is worth emphasizing that a perfect adhesion between FRP and the support is assumed, thus reducing the model parameters to those governing the constituent mechanical response, known a priori with a sufficient accuracy.

Overall response in terms of reaction force versus tangential slip, and local delamination mechanisms are simulated by varying the width of FRP reinforcement sheet. The plane-strain situation [1] is recovered as a particular case, namely when the FRP reinforcement covers the whole brick. In the intermediate situations, it is found that the damage of the brick starting
from the anchorage propagates inside the brick deeply, to form a difficulty predictable three dimensional surface, governing the collapse mechanism. Energy dissipation can be activated over such collapse surface, with the general beneficial effect to increase both the peak resistance and the ductility of the pillar response. The overall response obtained by the proposed model as a function of the reinforcement width, is then formulated in terms of an equivalent interface relationship tangential stress-slip and finally compared to the bi-linear interfacial relationship proposed by the Italian code CNR DT200 [6].

Traction distributions at the interface between FRP and the support are analysed in the linear and non-linear range (e.g., see also [3]). It is observed that the presence of mortar joints results in a sudden local change of tangential actions in the region immediately near the joint, and that the 3D transversal effect may not be neglected for some values of the ratio between FRP and pillar width. Finally, recourse is made to a simple analytical model, apt to predict value and location of stress peak along the interface, as well as the decay trend of the peaks.

REFERENCES