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The efficiency of mechanical anchors in CFRP strengthening of masonry: An experimental analysis

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ABSTRACT

Fiber reinforced composite materials are widely used for structural rehabilitation and retrofitting of existing buildings. Failure of not anchored CFRP reinforcements, applied to both concrete and masonry, mainly occurs in the substrate or at the bonding surface, for load values lower than the tensile strength of the composite. Mechanical anchors can effectively increase the maximum load of this type of reinforcements. Particular attention should be paid to the design and sizing of mechanical anchors so that these can produce adequate increments of both strength and ductility of the reinforcement. At the moment there are no specific rules or reliable predictive formulas that adequately support designers in the design choices and sizing of anchors. Of course, these can be defined only after collection of an extensive experimental database that highlights the peculiar characteristics of these reinforcements also with reference to the substrate material. In this context, the present work describes the results of an experimental campaign carried out on brick specimens reinforced with CFRP strips, anchored to the substrate by CFRP spike anchors. Almost all research in the literature about this topic refers to the use of this reinforcement technique for concrete structural elements. Studies concerning masonry are limited: this work contributes to bridge part of this gap. Plane CFRP reinforcement strips generally exhibit brittle failure mode. The experimental campaign reported in this paper shows that properly designed mechanical anchors increase both the failure load and the ductility of the reinforcement.

1. Introduction

Several consolidation techniques based on bonding composite materials, and particularly CFRP (Carbon Fibers Composite Polymers) strips, are more and more used in the past decades for the rehabilitation and the reinforcement of both concrete and masonry structural elements. The excellent mechanical performance of these reinforcements, combined with lightness and simplicity of application, justify their widespread use in the structural field.

Experimental analysis carried out on concrete [1,2] and masonry [3–7] structural elements reinforced by CFRP strips subjected to in-plane loads, have shown that failure generally occurs in the substrate, a few millimetres below the bonding surface. The load is transferred to the substrate mainly through shear stresses that produce cohesive debonding at a failure load lower than the composite tensile strength. Shear stresses are mostly concentrated in a limited portion of the reinforcement whose length is called "effective bond length" [8]. The failure load of a reinforcement strip increases with the bond length until it reaches such a limit length; longer bond lengths do not significantly increase the peak load, but only the reinforcement "ductility": while the load remains constant (at failure), the stress transfer zone moves from the loaded to the unloaded end of the reinforced surface.

Various numerical models can describe the mechanical behaviour of plane CFRP reinforcements. Interface cohesive zone models as well as continuous damage models [12] have been proposed in the literature to schematize the mechanical behaviour of such reinforcements applied to concrete [9,10] or masonry [11] structural elements. As previously said, failure of plane CFRP reinforcements, applied to both concrete and masonry, mainly occurs in the substrate or at the bonding surface. Therefore, the maximum load, lower than the composite tensile strength, strongly depends on the mechanical properties of the substrate. Several methods have been proposed in the literature to increase the maximum load of this type of reinforcements, especially with reference to concrete structural elements [13,14]. "U-wraps" anchors have been used, for example, in [15] to increase the bending strength of concrete

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