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Residual Strength and Durability of Glass Fiber FRCM and CRM Systems Aged in Alkaline Environments

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1 Introduction

Masonry constructions represent the largest part of the European architectural and cultural heritage. The most of these buildings were constructed according to the common practices of the period, disregarding any provision regarding the earthquake forces. In order to prevent damage they need to be strengthened, and in consequence of seismic events repair is often required. The structural vulnerability against horizontal forces is typically due to shear loads that produce damage to masonry walls and cracks in vaults. This could cause as far as collapse of the entire building. Therefore, preservation and retrofitting of masonry buildings in seismic regions is always a mandatory issue. Due to the large variability of masonry structural types, with regards to the different materials and geometries, a deeper knowledge of the buildings is necessary, when talking about existing masonry buildings, in order to adopt the best strengthening solutions.

In the last period, that extended from 1980 up to now, traditional retrofitting systems have been replaced by alternative techniques, i.e. the innovative materials called EBR (Externally Bonded Reinforcement). Fabric Reinforced Cementitious Matrix (FRCM) and Composite Reinforced Mortar (CRM) systems are Externally Bonded Reinforcements (EBR) made by fibrous meshes embedded in a cementitious/lime inorganic matrix. At present, these materials are used for strengthening, retrofitting and repair of existing masonry structures. A large use is expected in historical buildings, due to the specific criteria of conservation and compatibility with the substrate that need to be fulfilled. These materials, in fact, results more compatible with masonry substrate because of the inorganic matrix, instead of polymeric resin used for the well-known FRP (Fiber Reinforced polymers) composites.

The recent use of these new materials in civil engineering is not yet strongly supported by complete guidelines, especially as it regards the behavior in the long term. Their durability can be defined as the ability to resist cracking, oxidation, chemical degradation, delamination, wear, and/or the effects of foreign matter damage for a specified period of time, under the appropriate load conditions and under specified environmental conditions. In fact, EBR materials, being externally applied on structures, might be prone to detrimental action of harsh environments. Therefore, in order to properly define the service life, the performance of materials and interfaces in the long-term becomes a key issue. The problem of durability, for polymer composite materials was widely investigated, in the case of FRPs. On the contrary, the durability of FRCM and CRM systems represents a new research field, as a consequence of the lack of experimental results. In fact, few works are reported in technical literature about durability of mortar-based reinforcement systems.

The results of a large experimental program are presented in the paper. The research was focused on the durability of FRCM and CRM systems and their single components, namely dry glass fibers, resin, pre-cured glass fiber grids and mortar matrix. In fact, in order to better understand all the possible effects due to aggressive environments, in which the reinforcement may work during its service lifetime, it is necessary to investigate in depth, not only the behavior of the entire system, but also the effects on the chemical, physical and mechanical properties of constituents. This strategy would be able to provide technical recommendations and, then, establish useful equations to be used in the standard codes.

The ageing conditions investigated herein consists of different alkaline environments. The samples have been immersed in three different solutions, that simulate the chemical aggression of lime mortar matrix, Portland cement matrix and standard alkaline solutions (ASTM standard), for four exposure times: 500hrs, 1000hrs, 2000hrs and 3000hrs. In order to study the accelerating effects, different protocols were studied by increasing the conditioning temperature, from 23°C to 40°C and 70°C. The decay of the mechanical properties is reported for the whole strengthening system and for each of the constituents.

The results in terms of residual mechanical properties and physical damage are discussed in the paper. The evolution of degradation of internal reinforcement depends on a many factor such as the nature of fibers, manufacturing process, impregnation or non-impregnation, the presence of sizing layer, thermal features, and exposure environments. In addition, embedding fibers into inorganic matrices complicates the durability of the composite systems, because of the combination effects, i.e. interface, mortar, and various environmental and mechanical conditions. In fact, the inorganic matrices adopted to replace the resin for FRP, are characterized by high alkalinity, with a pH level equal to 12 ÷ 13, depending on the design mixture and the type of binder used (for example cement or lime). This alkaline environment damages glass fibres and causes embrittlement and loss in strength. The study of the durability of FRCM/CRMs becomes, hence, a very complex commitment.

The experimental data may be used to produce a deterioration model that can describe the long-term behaviour of samples after exposure to alkaline environments. In this study the retention of tensile strength of FRCM/CRM coupons, exposed to alkaline solutions, was used to predict the tensile properties in the long term, based on the Arrhenius model.

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