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A MULTI-PHYSICSAPPROACH APPLIED IN MASONRY STRUCTURES BASED ON NON-HYDRAULIC LIME

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ABSTRACT

There is a significant quantity of historic constructions with masonry structures built with binders based on non-hydraulic lime mortars in Portugal, as well as around the world (Lourenço et al. 2006). Even though historic buildings have quite important cultural, artistic and architectural value, their accurate structural safety quantification is often overlooked, or judged with quite simplified analysis models.

After placement, the mortars made with non-hydraulic, harden gradually from the exposed surface towards the interior due to reaction with carbon dioxide (CO_2) present in the atmosphere (carbonation process), thus promoting non-uniform mechanical properties of the mortar present in the masonry. In masonry structures, mortars have been acknowledged as the main cause for deformations and movements (Binda 2000). Therefore, the detailed characterization of mortars is of paramount importance for a realistic understanding of the structural behavior of this typology of structure (Lourenço 1996).

In spite of the complexity stated above, the stress analysis of masonry structures has been traditionally carried out with recourse to conventional structural analysis methods that solely consider the mechanical behavior of the masonry and neglect a range number of physical/chemical interactions that affect structural behaviour (Degrise et al. 2002). This PhD project aims to establish a multi-physics approach to the numerical simulation of the structural behavior of historic buildings comprised of masonry with non-hydraulic lime (with possible extension to other binding materials). Such multiphysics approach shall comprise the explicit computation of temperature and moisture states within the mortar, which interact with the penetration of carbon dioxide into the pore structure and the carbonation reactions. The resulting numerical framework can there be referred as a thermo-hygro-carbo-mechanical simulation. A series of experiments for model validation and parameter estimation will allow the sustained implementation such numerical framework (Saetta e Vitaliani 2004). This multi-physics framework should help a better understanding of the behavior in this kind of structures throughout time, while dully accounting the influence of environmental conditions, such as temperature, humidity and CO_2 concentration. Although there are several previous studies focused on the multi-physics simulation on concrete, such as those related to temperature (Azenha 2009 and Saetta and Vitaliani, 2004), moisture (Azenha 2009 and Elsen 2005), and carbonation (Saetta and Vitaliani, 2004), the present PhD project has the task of extending the applicability of such models to non-hydraulic lime and understand the coupling that exists between them.

The main tasks of this research work, which has begun approximately one year and half ago, are summarized in the following paragraphs.

Small scale tests are to be performed on non-hydraulic mortar samples, with controlled temperature, humidity and dioxide of carbon concentration. These experiments should allow isolating the effects of the several parameters involved in the simulation, assess the coupling between phenomena and establish the grounds for a systematic characterization procedure for numerical simulation. The experiments shall be further extended by applying a recently developed methodology for continuous stiffness assessment based on modal identification of specimens (Azenha 2009). Such testing procedure will allow the assessment of the relationship between carbonation depth and the stiffness of lime mortars, which an important coupling issue between the carbonation and mechanical fields.

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In order to measure the carbonation profile of mortar, two distinct techniques are currently being used. In terms of quantitative types of analyses, thermogravimetric (TGA) has been adopted, as it allows quantification of portlandite and calcium carbonate (Villain et al 2007). It is generally applied to hydrated cement pastes, concrete, hydraulic and non–hydraulic lime(Groves et al 1991; and Villain et al 2007). Phenolphthalein indicator shall be used as a complementary testing rechnique (Groves et al 1991).

Along with the experimental work, and based on the lessons learnt from experimental results, the implementation of the thermo-hygro-carbo-mechanical numerical framework is in development. The thermal transport model, such as humidity and carbonation models are initially implemented in 1D using the finite difference method (flows are essencially one-dimensional in masonry structures). In regard to mechanical model, as no new implementations are expected, the commercially available DIANA software will be used.

In a second phase, the implemented thermo-hygro-carbo-mechanical analysis framework will be applied to real structures and is expected to allow demonstrating the relevance of using multi-physics approaches in a better evaluation of stress states.

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