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MICROMECHANICS-BASED MODELS OF COCCIOPESTO MORTARS

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Abstract: *The paper deals with homogenization and strength estimation of mortars containing crushed bricks or other clay products. These mortars, known as cocciopesto, were used mainly during the Byzantine period and by Romans. Cocciopesto exhibit quite extraordinary mechanical properties due to formation of C-S-H gel coating on the interface between lime matrix and crushed clay products. Based on literature study, it seems that no one has ever tried to estimate the properties of cocciopesto mortars using micromechanical modeling. The micromechanical approach and Mori-Tanaka homogenization technique provided an explanation for the characteristic behavior of these mortars, but they had to be modified for homogenization of coated particles. Mortar strength was estimated from magnitudes of the quadratic average of deviatoric strain in individual phases. The calculations confirmed the important role of the C-S-H gel coating on the mortar strength and stiffness. Despite the above mentioned simplifications and a few uncertainties, the model seems to be able to correctly predict the trends and serve for an optimization of the mortar composition towards desired properties.*

Keywords: ***cocciopesto, micromechanics, Mori-Tanaka method, C-S-H gel coating, strength estimation***

1. Introduction

Lime mortars with addition of crushed clay products were used mainly during the Byzantine period and by Romans. Phoenicians were probably the first ones who added burnt bricks, tiles or pieces of pottery, to the lime mortar in order to increase its durability and strength. Romans used this type of mortar in areas where other natural pozzolans were not available and called such material *cocciopesto*.

By a closer investigation, it was found that the mortars containing crushed bricks exhibit a hydraulic character due to formation of C-S-H gel on the lime-brick interface. It was reported in many papers, dealing with the cocciopesto mortars, that a thin layer of the gel forms at the interface if the bricks are made of clay and burnt at the appropriate firing temperature. Since the C-S-H gel is responsible for some extraordinary properties of Portland cement concrete, it is conjectured that also the enhanced mechanical properties of the lime-crushed brick mortars can be attributed to the relatively high strength and stiffness of the C-S-H gel coating. The addition of crushed bricks should ensure the mortar hydraulicity, and therefore improve mechanical properties of the mortar, without need for modern artificial substances or industrial by-products such as metakaolin or fly ash.

The goal of this work was to investigate the role of the C-S-H gel coating on the mortar behavior from the micromechanical point of view and provide a tool for the estimation mechanical properties based on mortar composition. Works of previous authors (e.g. Pichler and Hellmich (2011)) provided an inspiration for the development of micromechanical models. These works deal with composite materials, composed of a matrix, voids and aggregates and exploit the method of Mori-Tanaka to estimate the effective stiffness and strength of the composite. It is assumed that only the deviatoric stress is responsible

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for a failure of the material, therefore the quadratic average of the deviatoric stress in the lime matrix was chosen as an adequate indicator for the determination of mortar strength.

Based on literature study, it seems that no one has ever tried to estimate the properties of cocciopesto mortars using micromechanical modeling. The micromechanical approach and Mori-Tanaka homogenization technique provided an explanation for the characteristic behavior of these mortars, but they had to be modified for homogenization of coated particles. Mortar strength was estimated from magnitudes of the quadratic average of deviatoric strain in individual phases.

2. Conclusions

The micromechanical study confirmed the important role of the C-S-H gel coating on the mortar strength and stiffness. Despite the above mentioned simplifications and a few uncertainties, the model should be able to correctly predict the trends and serve for an optimization of the mortar composition towards desired properties.

In particular the calculations based on micromechanical approach confirmed that the C-S-H gel formation on the matrix-crushed brick interface has a major influence on behavior of the cocciopesto mortars and the main factor influencing the behavior of the crushed bricks (or other clay products, such as tiles or pottery) in a mortar is the ratio of coating thickness to crushed brick size. It was also found that the addition of crushed bricks, having a bigger diameter, should make the mortar more compliant and cause an increase of the deviatoric stress in the matrix. The addition of crushed bricks of a small size results in the opposite behavior - the mortar becomes stiffer and the deviatoric stress in the lime matrix is reduced, ensuring a higher mortar strength. The proposed model also confirmed a negative effect of voids in lime mortars, since the increased porosity causes quite large increase of the deviatoric stress within the lime matrix, and therefore reduces the mortar strength.

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