Splitting Test on Masonry Cores and modeling of the Confined mortar behavior based on fracture energy

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ABSTRACT

The in situ evaluation of the masonry mechanical properties is a very complicated task. A viable alternative is based on the use of brick cores including a central mortar layer lying on a symmetry plane. In fact these specimens can be extracted very easily by cutting cores spanning two bricks at least. The obtained core is then subjected to a splitting test with a set up providing a different inclination of the mortar layer with respect to the loading plane.This type of test is similar to a diagonal wallet test and induces a mixed compression – shear stress state in the central mortar layer. In here, This test is used for masonry with sand and cement mortar. By using a Mohr–Coulomb failure criterion the test result can be interpreted in order to obtain all the mechanical properties of the masonry. This test can be a good alternative to other semi-destructive tests, especially the shove test. The latter test has defect, that's due to the lack of effect of dilatancy in the shear behavior of mortar in the shove test, the values obtained in terms of cohesion and friction angle will be greater than the actual value. In the following, a 3D continuous micromodel is presented in order to predict unreinforced masonry behavior. Due to the difference in the modulus of elasticity, the Poisson ratio and the thickness of the brick and mortar, several efforts have been made to simulate the compressive behavior of the masonry using different models with different goals and results. To examine this behavior, which is influenced by the interaction of units and mortar, in one hand, two-dimensional models are not able to consider 3d confined effect. On the other hand, the three-dimensional models are not able easily to control the effect of 3d confined and dilatation explicitly. The proposed model is based on the concept of micro-plane and is developed to model failure in masonry structures.

KEYWORDS

Core test, Micro modeling, Multi-laminate model, Confined effect, Dilatancy effect

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1. Introduction

In order to check the existing structures, the in-situ characteristics of the nonlinear sliding-shear behavior in the mortar-brick joint are very important. There are various standard test methods in this field. one of the most important of in-situ method that causes minimal disturbance to the integrity of the wall, is introduced by ASTM C1531-16[1], known as the ‘‘shove test” or ‘‘push test”.To perform a mortar shear test, technicians must constantly monitor the deformation of the masonry wall. This is to prevent unwanted cracking in the other part of the wall so that the uncertainty of this test is a reasonable amount. But the problem is that due to the lack of consideration of the effect of dillatancy in the mortar's shear behavior (which increases the existing vertical stress), the resulting values for adhesion and friction angle will be larger than the actual value.

To compensate for these shortcomings, a series of non-standard tests have been presented by researchers. In many cases, a suitable alternative is to consider Minor-destructive testing (MDT), which consists of removing small samples for testing in the laboratory. One of these tests is the masonry core with one mortar joint that In the present work, this method, which was previously investigated for low-strength mortars (sand-lime) [2], in the case of medium-strength sand-cement mortars (grade 1 to 5 and 1 to 6), are investigated.

Also, a numerical model for simulating the behavior of cores is presented in the form of micro-modeling. In this modeling method, we are able to model mortar and brick separately and analyze the behavior of each. Due to the difference in modulus of elasticity, Poisson's ratio and thickness of brick and mortar in masonry, several attempts have been made to simulate the compressive behavior of masonry using 3D models with different goals and results. This behavior, which is influenced by the interaction of units and mortar, may be strongly influenced by out-of-plane effects [3].

It is stated in reference [4], when the behavior of elastoplastic brick is considered, there is no need to consider a pressure cap for mortar in buildings under pressure. However, in reference [5], according to numerous laboratory observations, it is suggested that due to the failure of mortar in a resistance higher than the uniaxial compressive strength, the behavior of mortar in a highly confined form (with increasing strength and ductility) should be considered.Considering the shortcomings of the simplified micro-models (bricks + interface element)[4] and detailed ones (bricks + interface element+ mortar) [5], in terms of the difficulty of modeling, the large number of degrees of freedom and the heterogeneous development of stress at the location of the interface element and Also, the shortcomings of two-dimensional models (not considering the triaxial behavior of mortar and brick), the need for a strong and yet simple three-dimensional model seems necessary. In the current research, the continuous micromodel (mortar+brick) presented in reference [6], which is written based on multi-plane theory, is improved and used for confinement-dependent behavior based on fracture energy.

2. Laboratory study

Cylindrical samples were extracted from two masonry wallets with the dimensions of 700×400×110 mm^3, 60 days after their construction. Horizontal core drilling was done perpendicular to the surface of the walls (Figure 1-a) using a 100 mm diameter core.
In the mechanical interpretation of the experimental results of the core test using continuum mechanics theory, the mortar joint is observed as continuous (and not an interface element) under the conditions of triaxial stress.

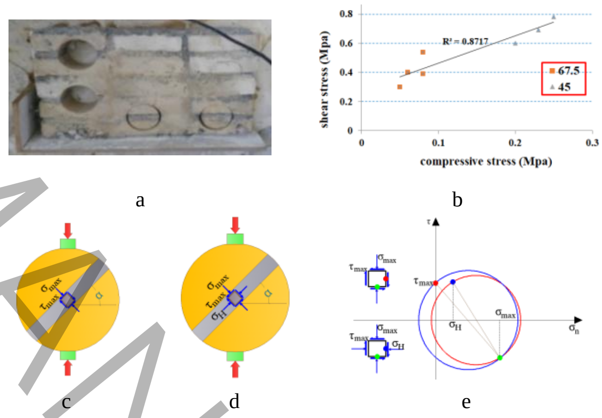

Fig.1:a-Masonry wall with stacked bricks and core extraction from the wall, b-laboratory resistance parameters (c & ϕ), c,d- Brazilian tests with inclined mortar bands: state of stress at the moment of failure and e-Mohr's circle of stress state in confined versus unconfined conditions

The used yield function includes three independent functions(f_d, f_t and f_c) of the effective stress components:

$$f_d = |\tau| + \sigma_n . \tan\phi(\kappa_1) - c(\kappa_1) \quad (1)$$

$$f_t = \sigma_n - \sigma_t(\kappa_2) \quad (2)$$

$$f_c = \sigma_c(\kappa_3) - \sigma_n \quad (3)$$

Uniaxial unconfined compressive behavior is modeled using a parabolic compressive curve based on fracture energy. Laboratory observations show that under axial load, brick is in compression-biaxial tension stress state, while mortar is in triaxial compression stress state. The complete curve for the stress-strain response can be seen in Figure 2, here this model (nonlinear Mohr-Columb) is used to define the mortar behavior. In order to use the model in the analysis of building behavior, the parameters introduced in the previous section should be calculated by calibrating the multi-plane model. The required algorithm is used in the form of UMAT code in Abaqus software.

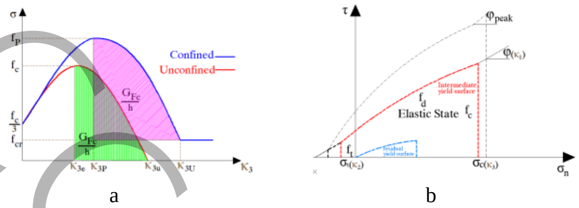

Fig.2:a-Axial strain-stress curve for confined mortar and b-Yield surface on a sampling plane in confined state

3. Simulation of tests conducted by Pela

In this part, the core test performed by Pela et al. [2], which was performed on masonry cylinders with dimensions 90 ×145 mm, is modeled. Then the samples tested in this research are examined.

4. Results and Discussion

Figure 3-a shows the comparison of the results of the present model for the core under loading and the discrete element method by Chen et al [7]. Due to the small dimensions of the samples, there is a lot of dispersion in the laboratory results. Nevertheless, the simulation results are within the range and close to the average value of the test data. Figure 3-b shows the comparison of core failure mode between the present model and tested cores in reference [2].

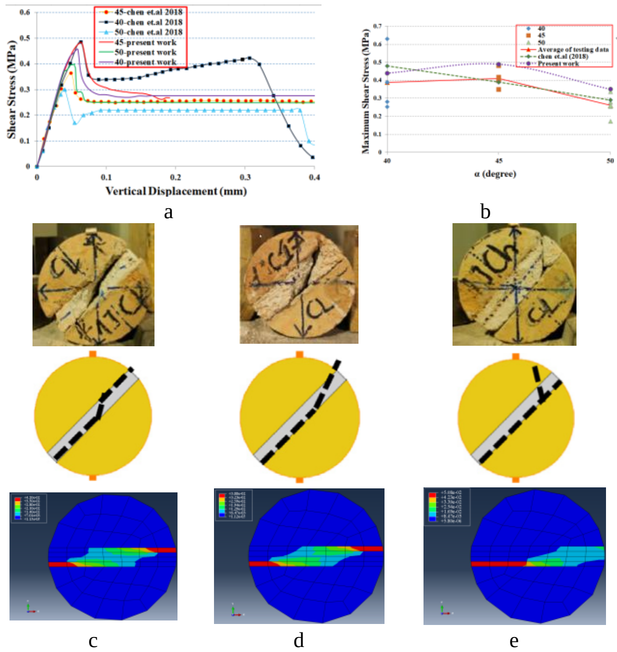

Fig.3:comparison between Simulation results for disc under diametrical loading : a- shear stress versus vertical displacement of loading plate for different mortar inclination with [7]; b- simulation and lab test results with [2] and [7], c-d-e- the failure mode of cores for different mortar inclination a-40 , b-45 and c-50

In the following, the behavior of the cores tested in the present work is modeled and the values obtained from the numerical analysis are compared with the test results (Figure 4). The obtained results show that similar to the laboratory work, the slip-shear failure mode along the mortar-brick interface is predicted for medium strength mortars.

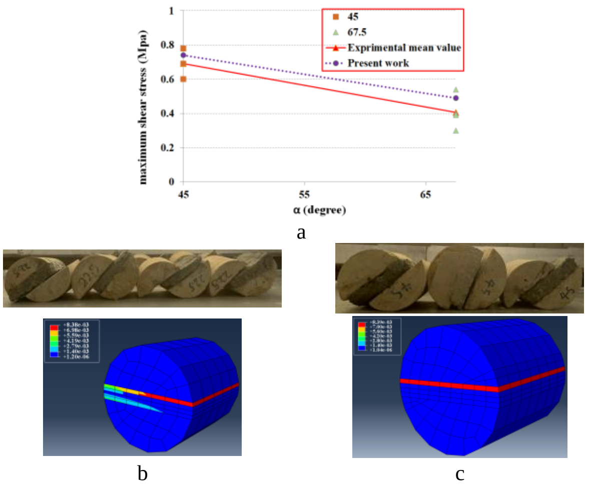

Fig.4-failure mode for angles a-67.5 degrees, b-45 degrees and c-Comparison of simulation and laboratory results in the present work

5. Conclusions

An alternative test to the mortar shear test is proposed to check the masonry building with cement-sand mortar, which is known as the core test, and then a simple yet strong three-dimensional model is introduced to check the behavior of the confined mortar. The results of investigation and comparison with other laboratory and numerical researches have been presented in support of the method.

6. References

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