Experimental and Numerical Study for Analyzing the Incompatibility between Materials used in the Restoration of Heritage Building in Morocco

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Abstract:This research work study the modeling the mortar-block assembly for analyzing the potential occurrence of mechanical problems at interfaces as the consequence of an eventual incompatibility. The study considers a heritage building located in Morocco. In this recent study the authors test the effect of non linear behavior of materials and interface. The goal of the modeling works is to compare the repartition of internal solicitations between the original situation and the restored one in order to quantify the risk, for materials that should be conserved, associated with the "stress shielding" phenomenon and to justify the particular attention to be paid for the choice of a specific mortar for interventions to be carried out on the concerned building.. One concrete numerical example using Abaqus code will be treated and showed on this paper.

Key words: numerical simulation, compatibility, stress shielding, elastoplasticity, contact, Abaqus

1. Introduction

A lot of historical monuments in the world have been built by masonry. Theses heritage buildings have been subject to different degradations due to several factors as temperature, water, mudslide…etc. In order to keep theses edifices for future generations, the local authorities was proceeding to continues restoration's projects. But, for non negligible cases the reparation operations was non durables. A few years after restoration, we can observe the same defaults which return. The used solutions aren't durables. One of the major damage noted is the destruction of the mortar by cracking. Morocco is one of the countries which contains the more important ancient heritage building, we cite University of al-Qarawiyyin at Fes (founded in 859 by Fatima FIHRIA), the first university in the world, mosques and minarets Kotobia (Marrakech, 12th century), walls : Bab Mansour in Meknes, Wall of Moulay Ismail, barrack (Kassaba Ismailia 17th century,….). In our precedent works [1,2], we was studying by numerical simulation the effect of

the incompatibly between ancient bloc and new mortar used in restoration operation. We chosen several virtual values for mechanical properties of materials. In order to improve our model, this once, we have characterized by experimental tests a real representative sample (bloc and mortar) and we created a new numerical model under Abaqus code. The case study is the ancient barrack (kassaba Ismailia) situated in the center of Settat town in Morocco.

University of al-Qarawiyyin, Fes, Morocco (founded in 859 by Fatima FIHRIA): the first University built in the world

Mosque and Minaret of Koutobia ,Marrakech, Morocco

2. Problematic

Typical of systems that may be encountered in Morocco, the masonry pattern constituting ancient mosque, minaret walls, castle, school, …As starting point for the first study presented in Simulia 2015 [1] we have chosen the walls of the mosqué Almasjid Alaadam in Safi. In Simulia 2016 [2] we presented an elastoplastic model applied to another monument near the University Hassan Premier. It is Al Kassaba Al Ismailia (Figure 1), an ancient barrack built by the monarch moulay Ismail in the 17th century, in old midina of Settat in Morocco, focusing on potential restorations that would affect the front wall. In its preliminary shape, the proposed parametric study will rely on numerical simulations carried out on an elementary cell that is representative of the masonry encountered in the wall (Figure 4).

Figure 1. Kassaba Ismailia in Settat, Morocco

Figure 2. Restoration works inside the barrack

Figure 3. Two years after restoration

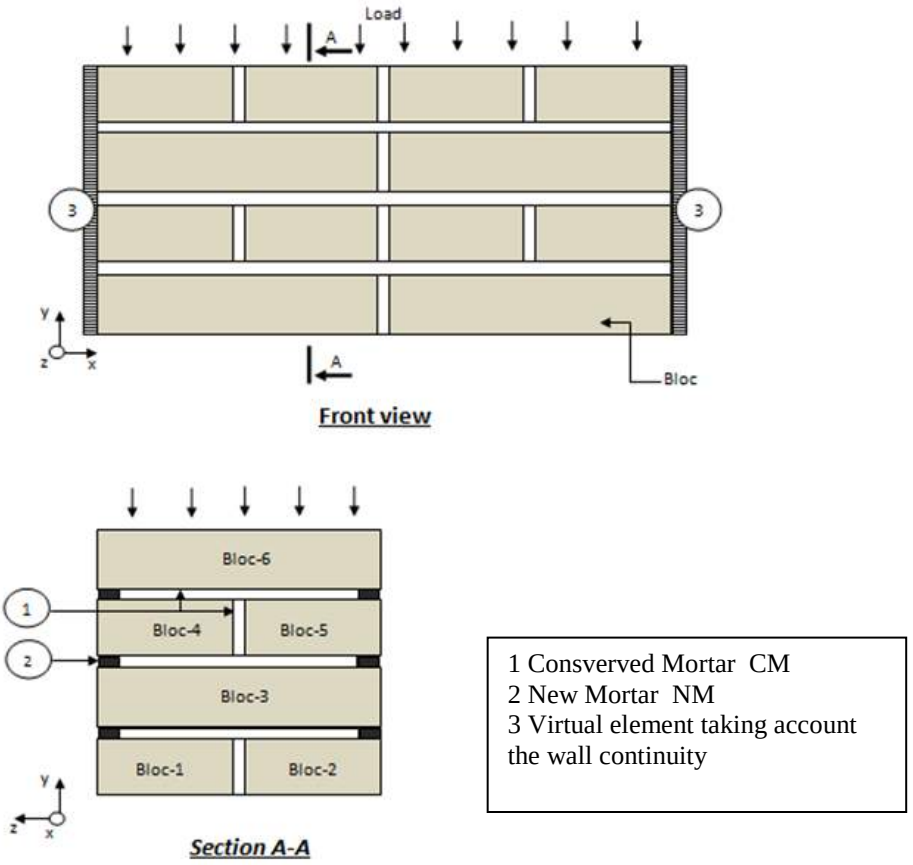

Figure 4. elementary cell

The elementary cell is composed of the conserved elements (block and mortar) and of the new mortar that is used for pointing both faces of the considered wall after weathered mortar material has been removed on a 2 cm depth. The preserved blocks are parallelepiped elements of 9 x 6 x 19 cm^3 and all the joints (head joints and bed joints) present a thickness of 1 cm. Due to its position inside the minaret wall, the cell is assumed to be impacted by a static load pressure of 10 daN/cm^2, taking the weight of above elements (wall and flagstone) into account. For replicating the natural confinement acting on the cell while circumventing edge effects, rigid plates are placed on the superior and under the inferior face of the elementary cell with hard contact and friction without sliding conditions and continuity conditions are imposed on lateral facets of the cell.

3. Preliminary numerical study

Numerical simulations are performed with ABAQUS software [5], coupled with Matlab which manages the parametric study and controls the ABAQUS calculation files. A tridimensional model

is considered. In this preliminary approach, homogeneous and isotropic linear materials are considered for the simulations.

Table. 1 – Mechanical properties of various materials used in the parametric modeling

Designation of Material	Modulus of Elasticity [daN/cm^2]	Poisson's ratio[-]	Density [kg/cm^3]
Conserved mortar	3 000	0.25	0.0020
Conserved block	120000	0.25	0.0020
New mortar	3000 and 90000	0.25	0.0020

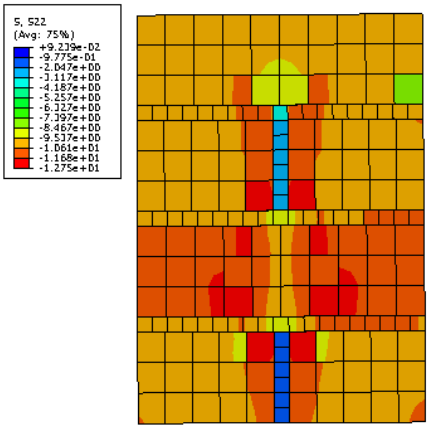

Figure 5. Diagramme of the normal stress distribution E_{NM} = 3000 daN/cm^2

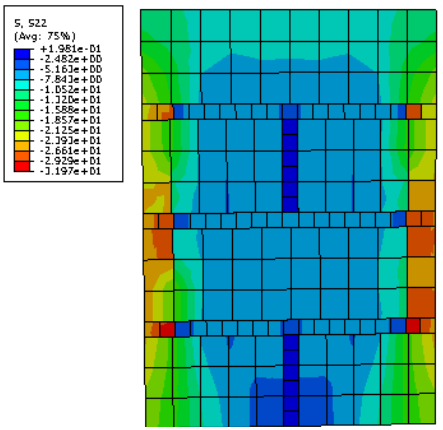

Figure 6. Diagramme of the normal stress distribution E_{NM} = 90000 daN/cm^2

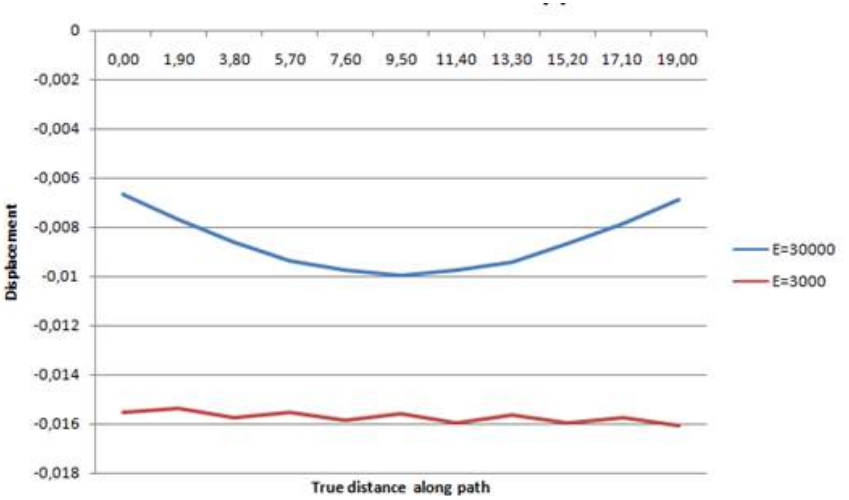

Figure 7. Deformation of the bloc at the top for different values of E_{NM}

For a compatible new mortar (E=3000 DaN/cm^2) the vertical stress and displacement are more uniform than the case with mortar incompatible (E=300000 or 900000daN/cm^2). Figure 7 show that the conserved structure bloc and mortar is submitted to an imported flexion than the new one and this part of structure risk fail down at any time. This result obtained by Abaqus is more important for the future numerical and experimental developments. It opened way to real solution for the problematic.

4. Preliminary experimental results

Actually we have just had a real representative sample of the wall of kassaba Ismailia, and characterized it by conventional compression test. The primelary test gave the following values of Young's modulus for different material used:

Conserved bloc 1 (Sand)	3980 MPA
Conserved bloc 2 (limestone)	28,89 MPA
Original mortar (Lime+clay)	5000 MPA
Ancient mortar after precedent restoration (2014)	32000 MPA
New mortar in the latest restoration (2016)	3,22 MPA

The presented results can be changed, because it's just one test realized last week on one sample. For reliable parameters, we are performing another several tests.
The work is still in progress, our objective is to use the real properties of the local materiel and perform a new numerical model with Abaqus giving solution to the present problematic. Our idea is to use in Abaqus, a composite material based in the same local material (clay) reinforced.

5. Conclusion

The present work proposes results showing that numerical simulation may be used for documenting the situation faced by practitioners in the restoration operations. The test of a non linear model shows that mechanical incompatibility plays a great role in the durability associated to restoration operations carried out on heritage masonry. A new improved numerical model is in progress. We searche to have, by simulations with Abaqus code, an adequate solution using a composite material based on clay. We hop that our new numerical model will be ready for the finale submission in Simulia 2017.

6. References

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