A non linear model for studying the interface's behavior bloc/mortar in a heritage building in Morocco and numerical modeling by Abaqus

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Abstract

This research work follows our first work presented in Simulia 2015 [1] about 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. An elastoplastic model including contact with friction and thermal conductivity is used. 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

Masonry has been used for centuries in many places around the world. Most of the master pieces of our heritage are then erected with this material. For several reasons, these heritage structures should be preserved in order to be transmitted to following generations. Although they may appear trivial, restoration works are easily impacted by parasite problems associated with incompatibilities between conserved and brought materials. These problems affect the durability of the operations and constitute an attractive subject for researchers engaged in structural mechanics.

Erectable with many types of bricks or stones with mortar joints according to varied patterns, the masonry concept concerns a wide range of building materials that are characterized by heterogeneous mechanical behavior [2]. Based on old constituents as clay and stone, and ancient techniques, heritage masonry may suffer of low mechanical properties still restricted by degradations induced by aggressive environments or exceptional conditions to which they are exposed [3,4]. In order to preserve ancient structures, restoration campaigns will generally opt for the replacement of altered parts by more reliable ones. Such kind of works carried out on masonries may sometimes concern bricks or stone but, in almost any case, will lead to partial mortar replacement (at least pointing operations). A specific attention should then be paid in the prescription of the works: contemporary elements should achieve a sufficient compatibility (mechanical, aesthetical, …) with the ones that are kept.

2. Case study

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. Actually we are working on one 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

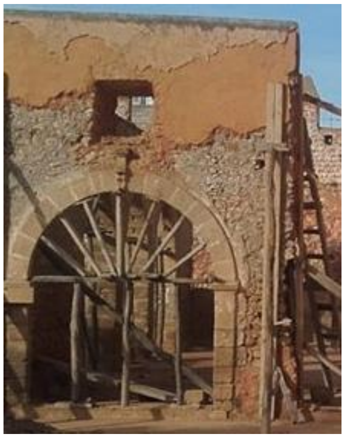


Figure 2. Restoration works inside the barrack

Figure 3. Two years after restoration

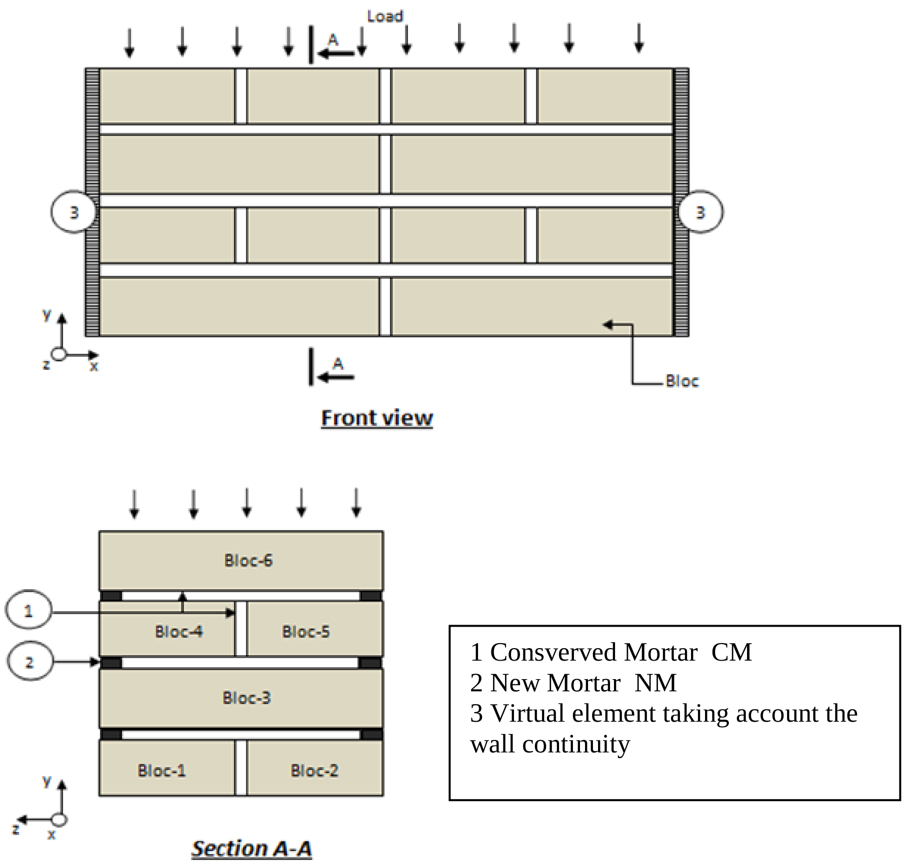


Figure 4. elementary cell

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. First study : Linear problem

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

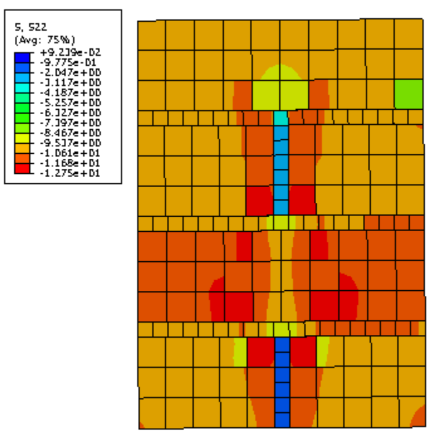


Figure 5. Diagramme of the normal stress distribution E_{NM} = 3000 daN/cm^2

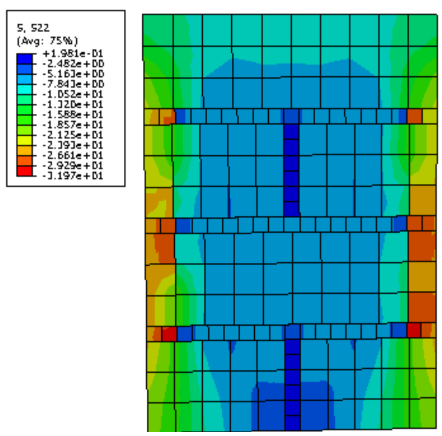


Figure 6. Diagramme of the normal stress distribution E_{NM} = 90000 daN/cm^2

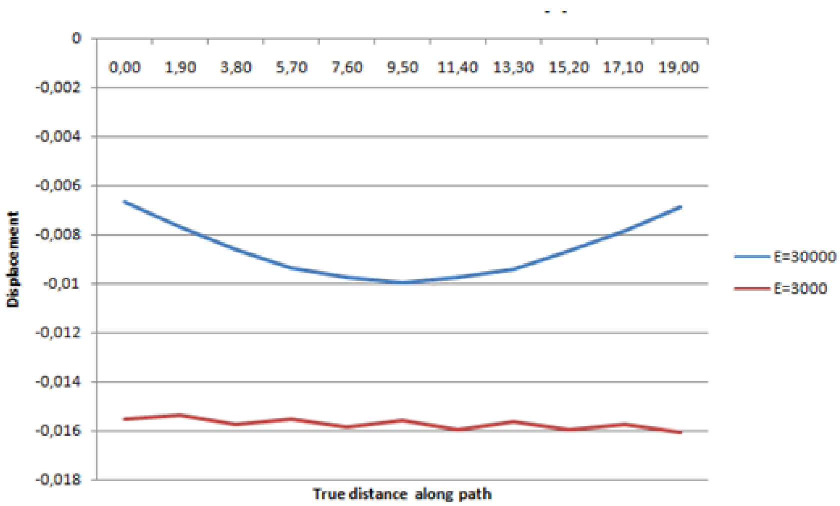


Figure 7. Deformation of the bloc at the top for different values of E_{NM}

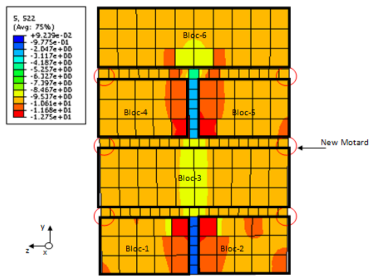
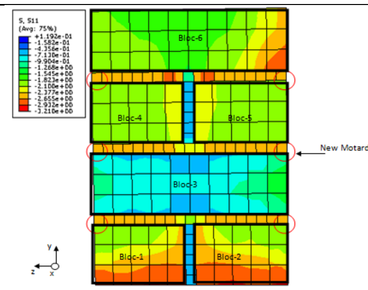
For a compatible new mortar (E=3000 DaN/cm^2) the vertical stress and displacement are more uniform than the case with mortar incompatible (E=300000 or 900000daN/cm^2). Figure 7 show that the conserved structure bloc and mortar is submitted to an imported flexion than the new one and this part of structure risk fail down at any time.

4. Non linear problem

Another studies and experimentations are in progress in order to approximate the real problem with multi physical phenomena effects as temperature, friction, porosity, crack...in this goal, we have began by testing an elastoplastic model involving thermal conductivity phenomena's. As example, the wall of the ancient Barrack in Settat (kassaba al Ismailia) built by masonry in 17th century by the Monarch My Ismail has been chosen.

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

Designation of Material	Modulus of Elasticity [daN/cm^2] E	Poisson's ratio[-] nu	Density [kg/cm^3] D	Thermal conductivity µ	Yield stress R_e	Temperature in °C
Conserved mortar “CM”	3000	0.25	0.002	0.002	20	20
Conserved block “CB”	120000	0.25	0.002	0.004	340	20
New mortar “NM”	3000 and 90000	0.25	0.002	0.002→0.003	20 →200	20
Virtual wall “VW”	120000	0.25	0.002	0.004	340	20

<table>
<tr><td>Noramal Stress tword axis y</td><td>Tangential stress toward axis x</td></tr>
<tr><td colspan="2">Case 1 : the new and the conserved mortar are identical</td></tr>
<tr><td>
</td><td>
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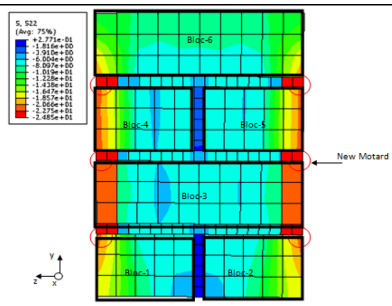
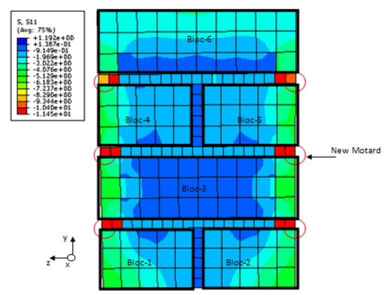
<tr><td colspan="2">Case 2 : E_{NM}=30xE_{CM}</td></tr>
<tr><td>
</td><td>
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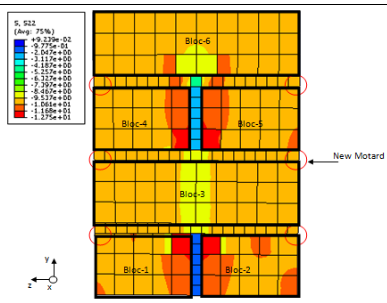
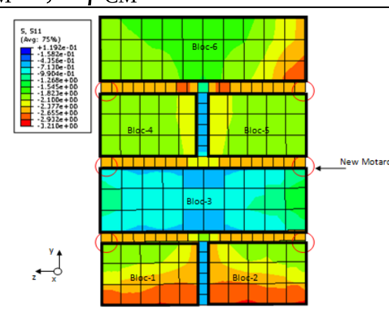
<tr><td colspan="2">Case 3 : μ_{NM}=1,5xμ_{CM}</td></tr>
<tr><td>
</td><td>
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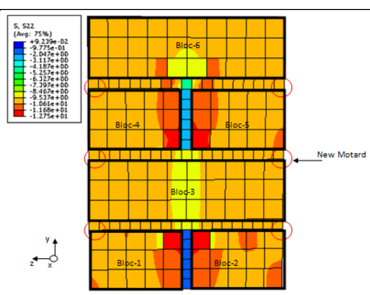
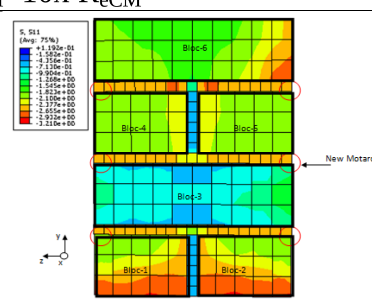
<tr><td colspan="2">Case 4 : R_{eNM}=10x R_{eCM}</td></tr>
<tr><td>
</td><td>
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<tr><td colspan="2">Figure 8. Diagramme of the normal and tangial stress for different cases</td></tr>
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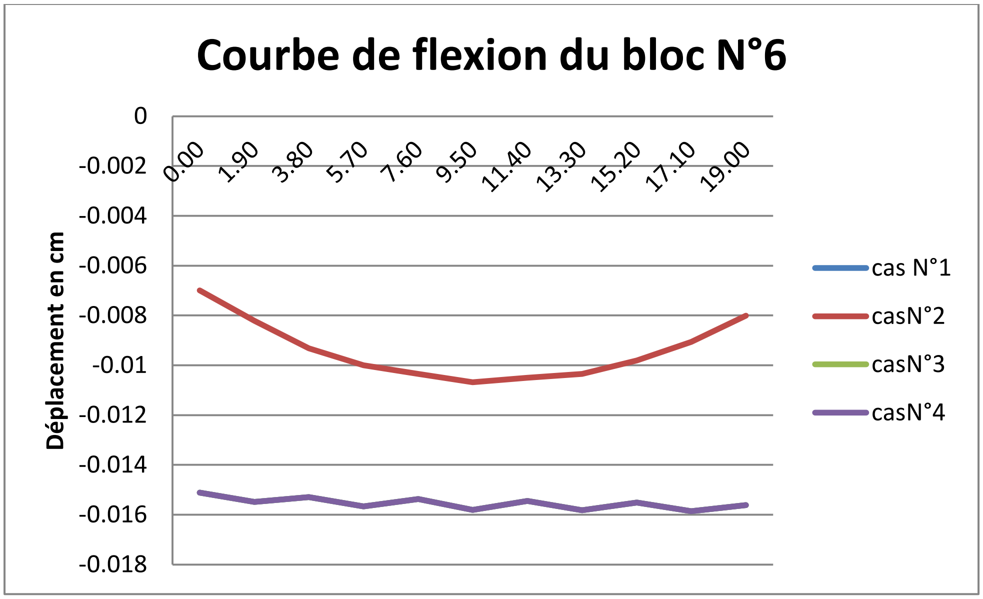

As summary of the presented results, we can conclude that the rigidity of the materials plays a major role in the stress and deformation repartition in the structure. These results confirm our first conclusion presented in *Simulia 2015 [1]*. At this step, we can't conclude that this non linear model gives or no new results because the work hasn't been achieved yet.

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. Nevertheless, encouraged by the presented observations, another investigations and experimentation are now in progress. We are characterizing a real bloc and mortar and research an adequate solution by using local durable material as clay reinforced.

6. References

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