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FEM Numerical Modelling of a Masonry Wall Strengthened with GFRP Strip

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Summary

This paper presents a study based on a comparison of multiple FEM analysis of a 604x240x115 mm masonry element subjected to out of plane bending. The behaviour of materials was changed in terms of stiffness to simulate the damaging effect. One strip of glass fibre reinforced polymer composite material was added at the bottom of masonry element. The results show the influence of the GFRP strip on the behaviour and the strength of the masonry. All the analyses were performed by ANSYS software.

Keywords: GFRP strips, masonry wall, FEM.

1. INTRODUCTION

The strengthening techniques of the masonry buildings have evolved continuously. Some of these are composite materials. These solutions have different requirements and different behaviour. Their advantages like lightweight or the application procedures make them favourite for some masonry buildings. After few experimental tests of multiple samples, a numerical model was necessary.

The study in the present paper shows ten numerical analyses. The objective was the understanding of the behaviour of a GFRP strengthened masonry element subjected to out of plane bending [1], [2], [3].

Seeing the stress or the displacement map distribution and their maximum values, in numerical modelling help future design scenarios. The approaching of the mortar layer stiffness is the key of FEM in this study because these layers are weaker than bricks in tension and the brick failure occurring due to mortar weakness.

2. MATERIALS AND NUMERICAL MODEL

For a more realistic modelling, all the components of the masonry and GFRP strip are solid parts. Each component is a unique block and simulates bricks, mortar layers and GFRP strip. Figure 1 presents the solid parts of the masonry beam,

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which have four end supports and one GFRP strip at the bottom side. Figure 2 shows the finite element discretization and loading scheme.

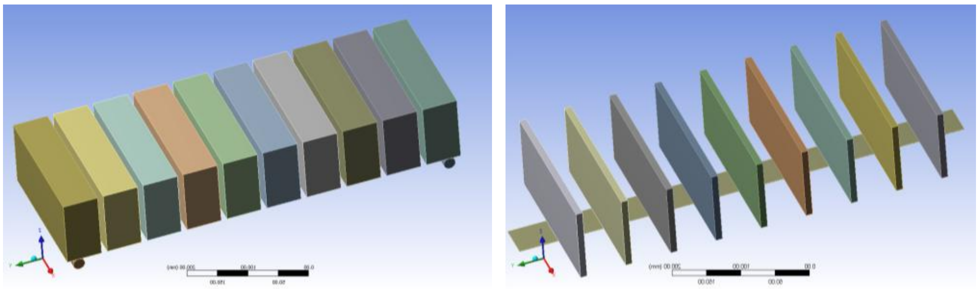

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Figure 1. The component parts of the masonry model:
a - bricks and end supports; b- mortar layers and GFRP strip

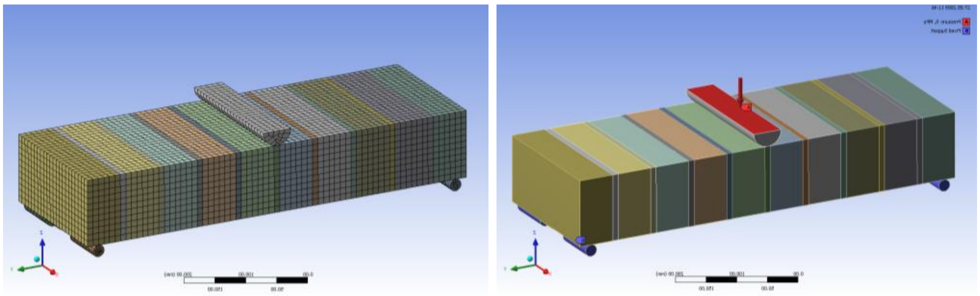

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Figure 2. a- finite elements discretization; b- loading scheme

Each of the numerical analysis uses material properties previously obtained from an experimental program. The mortar was labelled from Mortar 100%E to Mortar 5%E depending on the value of Young's modulus, which was reduced in 10 steps with 10%. Table 1 presents all the mechanical properties of the materials used in analyses.

Table 1. Materials properties

	Young's modulus (MPa)	Poison coefficient	Density (kg/m³)	Tensile Strength (MPa)	Compressive Strength (MPa)
Mortar 100%E	10000	0.18	2100	-	8
Mortar 90%E	9000	0.18	2100	-	8
Mortar 80%E	8000	0.18	2100	-	8
Mortar 70%E	7000	0.18	2100	-	8
Mortar 60%E	6000	0.18	2100	-	8
Mortar 50%E	5000	0.18	2100	-	8
Mortar 40%E	4000	0.18	2100	-	8
Mortar 30%E	3000	0.18	2100	-	8
Mortar 20%E	2000	0.18	2100	-	8
Mortar 10%E	1000	0.18	2100	-	8
Mortar 5%E	500	0.18	2100	-	8
GFRP strip	77000	0.28	2600	1500	-
Brick	18000	0.20	1900	-	20

The decreasing of mortar stiffness simulate the real behaviour and damage which occur in mortar layers.

3. RESULTS AND DISCUSSION

After the performing of the analyses, records of the overall behaviour and systematic results show variation at the interface between GFRP strip and masonry model. In terms of stress and displacement map distribution, figure 3 presents the maximum principal stress and strain meanwhile figure 4 present maximum vertical displacement and interface behaviour. In this step, mortar stiffness has Young's modulus of 10000 MPa. The first analysis results show that the maximum principal stress has a value of 48 MPa and is a tensile stress. This occurs in GFRP strip. The maximum displacement is 0.43mm in the middle of the model. At the interface of strip and masonry, there are two types of behaviour sliding with yellow colour and sticking with orange colour. The orange colour is exactly on the bricks surfaces, which means that the adherence is better on the bricks than the mortar.

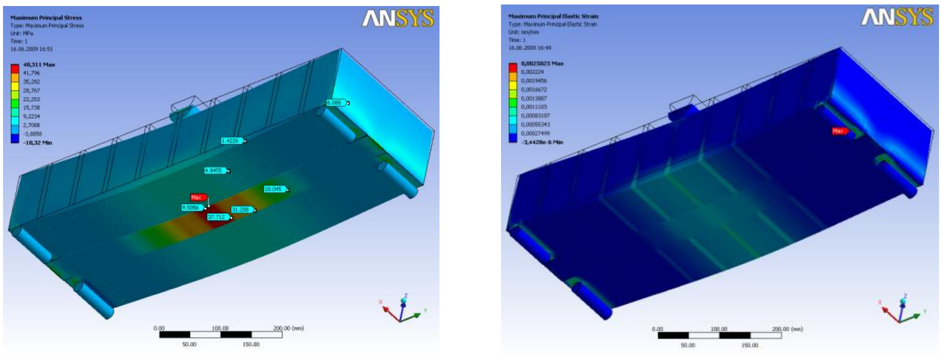

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Figure 3. First analysis results - E_m=10000 MPa:
a- maximum principal stress; b- maximum principal strain.

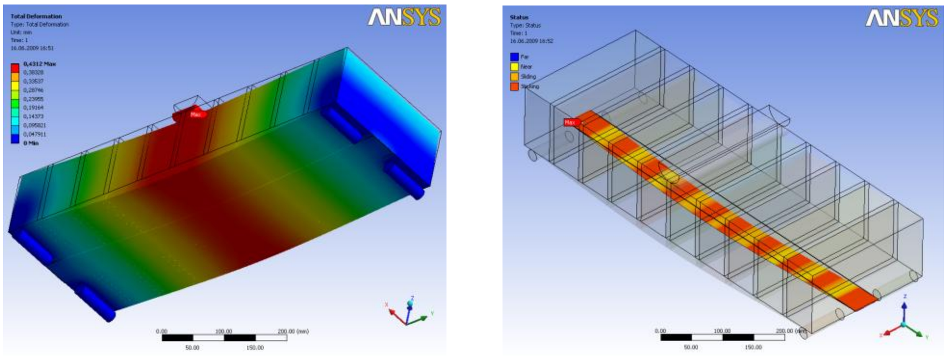

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Figure 4. First analysis' results - E_m=10000 MPa:
a- maximum vertical displacements; b- interface status.

Figure 5.a show the frictional stress distribution map on the GFRP strip interface side. Their distribution has a maximum tensile value of 1.5 MPa at the ends and 0.75 MPa in the middle. Another result consists in the mortar central layer pressure, at the interface between mortar and brick. The compressive value is 10 MPa and the tensile value is 8.8 MPa.

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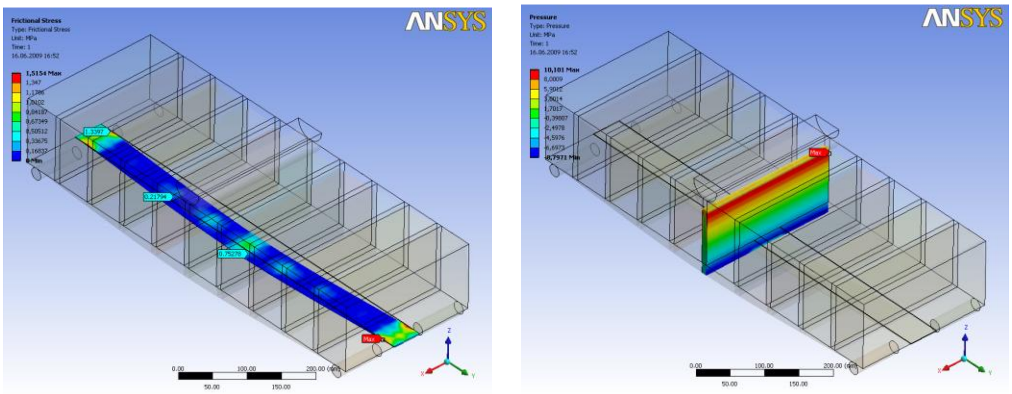

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Figure 5. First analysis' results - E_m=10000 MPa:
a- frictional stress distribution map; b- pressure on the mortar layer interface.

The reducing of the mortar stiffness almost ten times shows an increase of three times of the maximum value of maximum principal stress in the GFRP strip. In addition, the maximum principal strain occurs in the central mortar. Figure 6 shows their distribution map.

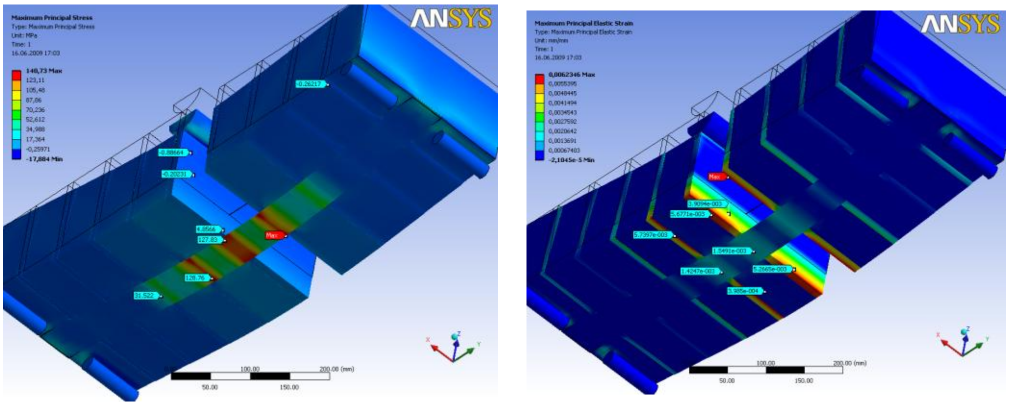

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Figure 6. The tenth analysis' results - E_m=1000 MPa:
a- maximum principal stress; b- maximum principal strain.

The frictional stress has an increase of 280% in the GFRP strip interface. In the same areas where the frictional stress are distributed the sliding distance occurs with a maximum value of 0.0001mm. Figure 7 presents the distribution map of these results.

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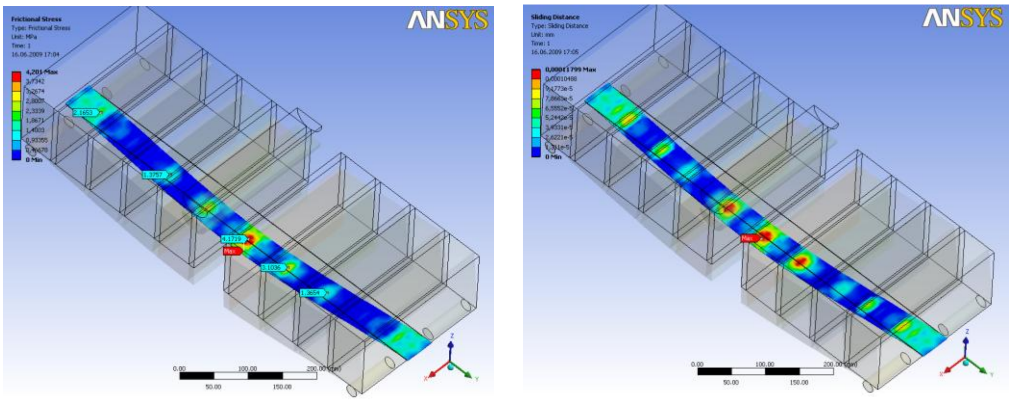

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Figure 7. The tenth analysis' results - E_m=1000 MPa:
a- frictional stress distribution map; b- pressure on the mortar layer interface.

The variation of mortar stiffness was reported to the maximum principal stress and frictional stress. Figure 7 presents these variation curves.

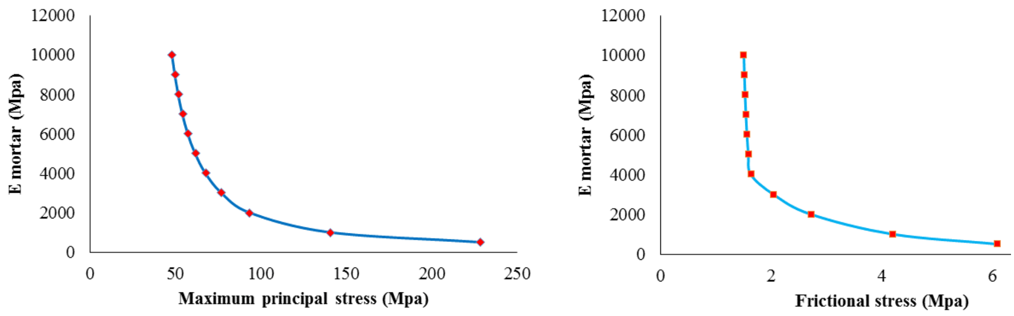

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Figure 8. The curve variation of stiffness reported to maximum principal stress and frictional stress at the GFRP strip interface

From these curves, it can be observed that the GFRP strip has an important role in the strength of the masonry wall element. This significantly occurs when the mortar was damaged and no tensile strength is present between bricks and mortar layers. The entire tensile stress is present in GFRP strip and in the interface area. The increasing of the maxim principal stress in the GFRP strip begins immediately, which means that the influence of strengthening is compatible with masonry. The vertical displacements are not significantly reduced by the presence of the strip, as was seen from the numerical analyses.

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4. CONCLUSIONS

The strengthening techniques for masonry walls is a permanent research subject due to massive masonry buildings and their importance. The preservation of these buildings which, sometimes are historical monuments, is important for each nation, especially for those, which have seismic areas. The use of GFRP composite materials is conducted by the strength, efficiency, lightness and minimum structural intervention.

This study presents an incremental analysis of the influence of a GFRP strip on a masonry element. These results show a good structural behaviour considering the worst scenario when the wall is subjected to out of plane bending and the mortar layer lost the tensile strength capacity. The adherence between bricks and GFRP strip is almost a bonded contact and the frictional stress, which occurs, can be taken by the adhesive strength. These results can be used for future design work in a masonry building rehabilitation project.

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