Analysis of 5 Floor Brick Masonry Building, Type 77/5

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Abstract

This study investigates the seismic performance and structural improvement of a five-floor Type 77/5 brick masonry building through both linear and nonlinear analysis methods. The research employs finite element modeling using ETABS software for linear analysis and AM-Quake for nonlinear analysis to evaluate building performance against Eurocode standards. Initial findings revealed critical vulnerabilities, including excessive displacement (12.91 cm versus the allowable 7.1 cm) and periods of oscillation (0.688 sec versus the recommended 0.366 sec). Multiple reinforcement strategies were systematically tested, including concrete cladding, full concrete wall replacement, and fiber-glass reinforcement, with limited success. The study ultimately demonstrates that selective column implementation in the first two floors provides the most effective and economically viable solution, reducing displacement to 42.19 mm in the plastic phase and bringing the period within acceptable parameters. These findings have particular relevance in the context of Albania's seismic activity, as evidenced by the 6.3 Richter magnitude earthquake of November 26, 2019, and offer practical solutions for similar masonry structures requiring seismic reinforcement in regions with limited economic resources.

Keywords: seismic analysis, masonry building reinforcement, structural dynamics, Type 77/5 building, finite element modeling, column reinforcement, earthquake resistance

Introduction

A masonry structure represents a behavior highly dependent on the reaction of the constituent elements: **BRICK AND MORTAR.** Brick had an elastic behavior in tensile and compressive, while the mortar doesn't behave like that. However, we can call it a homogeneous anisotropic material in terms of resistance and deformation. [Isai, C. (2009/10)**.** Structural Design Course, Lecturer at the University of Trieste]

The **study** includes analyzes based on **2 steps**:

Linear analysis, with the help of **finite element model**. (**Etabs Program**) *

Nonlinear analysis, performed with a **simplified modeling procedure**. (**AM-Quake**)[1]

The main results of LINEAR ANALYSIS

In the first steps of this analysis are identified the problems the building present, which are:

1- Displacement larger than allowed

2- Periods that exceed twice the recommended periods.

1- Displacement *(with gray lines the deformed shape of the building is presented*)

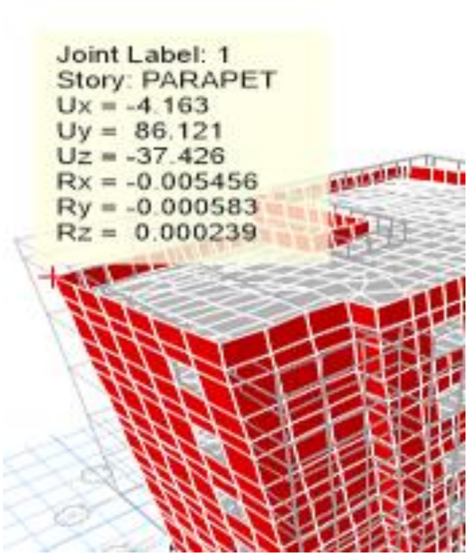


Fig. 3 – Displacements for the original building

Maximum displacement of the building, in the linear phase is Uy = 8.61cm > 7.1 cm, for the combination:

$$ELY: D + 0.3L + 0.3EQLX + EQLY$$

While in the nonlinear phase this displacement is:

$$8.61 * q = 8.61 * 1.5 = 12.91 \text{ cm} >> 7.1 \text{ cm}$$

2- Periods

[1] These 2 analyses have been published in other journals (EJERS and IJRAMR). For the purpose of this article we will refer below briefly "The main results of the linear analysis" only.

From the results of the modal analysis, for the combination ELY, the building manifests high periods in the first form of oscillation:

Mode 1 - Period 0.688960526380029

According to the recommendations of EC8, the period of self – oscillations, for masonry buildings, should be: $[T] = 0.05 \times Hg^{0.75} = 0.05 \times 14.2^{0.75} = [0.366]$sec << T = 0.688 sec !!!

Attempts and Recommendations for the Improvement of Displacements and Periods

To improve the 2 main parameters of the building, the displacements and the periods, several hypothetical ATTEMPTS were performed, which assume that we have the opportunity to change the different physical masonry parameters. The realized attempts are given in the following:

Attempt 1

Based on the layered option provided by Etabs, it was assumed that we add outside masonry a 75 mm thick concrete cladding. A version with 2 "integration points" has been accepted.

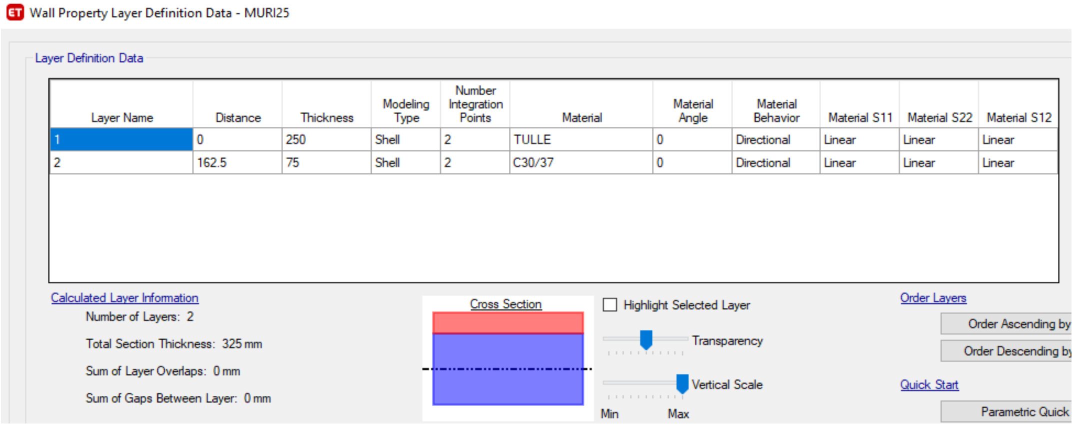
The results of this attempt are:

- The displacements are: Uy = **101.27**mm and Ux = **- 28.8** mm!!

- The period in Mode 1 is **0.677** sec:

Mode 1 - Period 0.677413244630805

The improvement is insignificant, the building continues to be flexible, the displacements in the plastic phase are 10.10 cm * 1.5 (ductility) = **15.15** cm, while they should be 7.2 cm!!! The period increases, also the displacements, although this increase is insignificant. We emphasize that the change of the integration point parameter does not affect the period and displacements of the building.



Layer Name	Distance	Thickness	Modeling Type	Number Integration Points	Material	Material Angle	Material Behavior	Material S11	Material S22	Material S12
1	0	250	Shell	2	TULLE	0	Directional	Linear	Linear	Linear
2	162.5	75	Shell	2	C30/37	0	Directional	Linear	Linear	Linear

Fig. 4 – Wall layered data C30/37

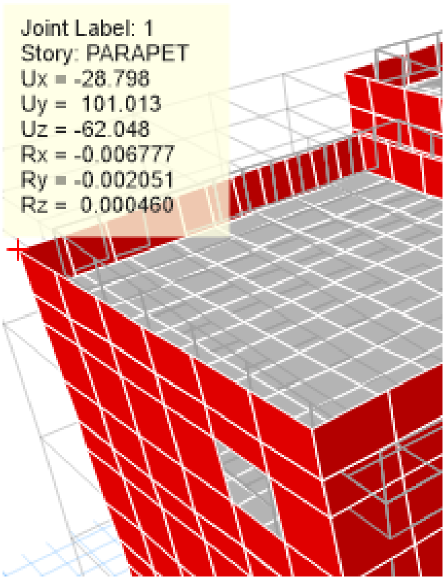


Fig. 5- Displacement at the top of the building for layered masonry.

Attempt 2

The same building is assumed to be built by concrete walls C30 / 37.

It has the same plan, all built from concrete walls, with a thickness of **20 cm**, except the brick partition walls, thick 12 cm, the same as the original design. The results are:

- Displacement: Uy = 87.32mm, Ux = -27.56 mm!!

- Period in the first mode: T = 0.613 sec

Improvements are insignificant, the change in displacements and periods for concrete structure is practically very small. That is, even the building is idealized with concrete elements, of high physical parameters, it's vulnerable again.

The replacement of the brick masonry with concrete, in this attempt, is realized to avoid any doubt regarding the idealization of brick masonry in "thin shell" elements, on ETABs, how they can be:

- A consequence of wrong acceptances on masonry parameters.
- Incorrect acceptance of masonry partition on shell elements.

Despite the fact that concrete has much higher physical characteristics than brick masonry, again the improvement on the above parameters, Periods and Displacement, are insensitive.

Several other attempts didn't give any target result. For shortening the article, I'm referring to them only one, that with **the use of Fiber-Glasses.**

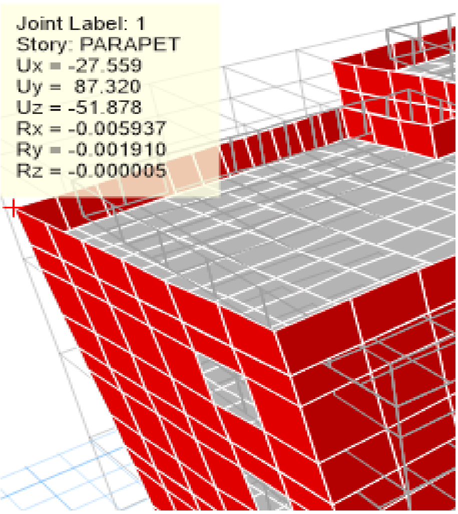


Fig. 6- Displacement at the top of the building in this attempt.

Attempt 3- The use of FIBER- GLLASES elements

The period for this case is 0.646 sec, the Uy displacement meet an insignificant decrease, it becomes 97.92mm

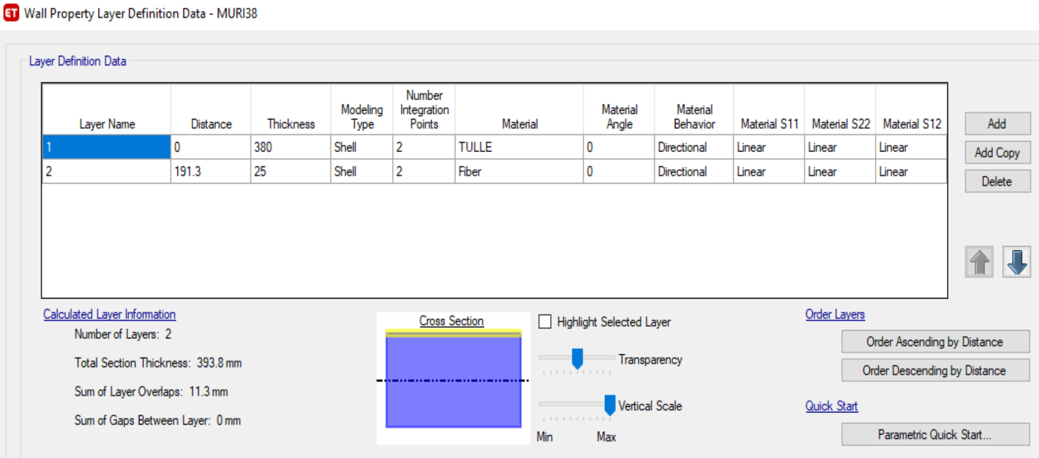


Fig. 7 - The fiber-glass layer on the outer wall of the masonry, for a wall of 25 cm

Key Features for Fiber- Glasses

QUALITIES	**Standard ASTM**	**22^0 C**
Elastic constants		**GPa**
Longitudinal module E_L	D3039	53-59
Transverse module E_T	D3039	16-20
Axial shearing module G_{LT}	D3518	6 -9
Poisson's coefficient **m** $_{LT}$	D3039	0.26-0.28
Resistance		**MPa**
Longitudinal traction F^T_L	D3039	1590-2000
Longitudinal pressure F^C_C	D3410	690-1240
Transverse traction F^T_T	D3039	41-82
Transverse pressure F^{CH}_T	D3410	110-200

In my opinion, reinforcement with FRP, in addition to the insignificant change of parameters, has high economic costs, for many reasons, which are not subject to this treaty.

Attempt 4: *COLUMNS only on the first 2 floors*

This is also the last attempt, which gave a satisfactory result.

In this attempt, finally, the Periods and Displacements have met the intended Target

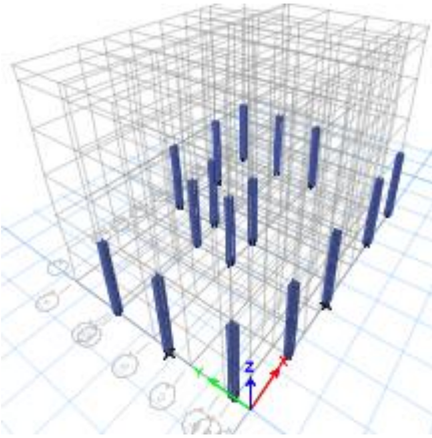


Fig 8- Columns in 2 floors

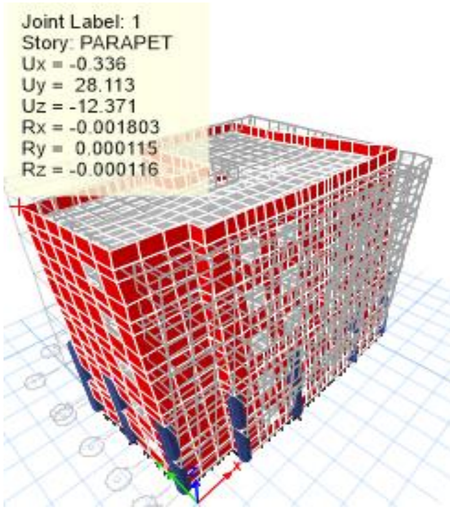


Fig 9- Displacement for ELY combination

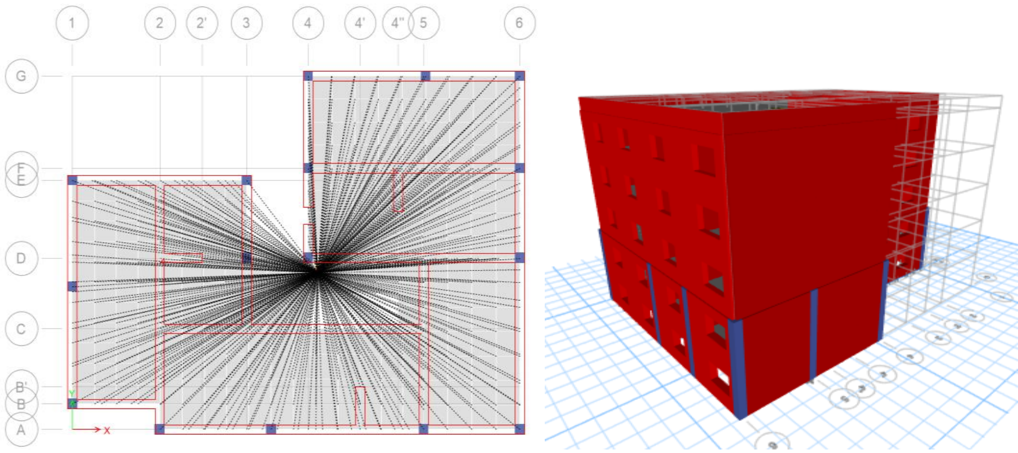


Fig.10 - The column position, in plan and in 3D.

a- The period in the first modal form was reduced to the value:

Mode 1 - Period 0.352056254329364

Remind that the allowed period per building is

[T] = **0.365 sec**

b- The maximum displacements for the ELY combination are reduced to the value:

Uy = 28.13 mm

In the plastic phase, these displacements will be:

$$28.13 * 1.5 = 42.19 \text{ mm}$$

They are now much smaller than the allowable displacements, [Ux] and [Uy] = 7.1 cm

Practically, the above results are very important for the following reasons:

1. Finally, we have a solution according to which the building has the displacements and periods within the recommendations of the Eurocode, consequently in case of an earthquake, the lives of the people lodging on them, are not endangered.
2. Is the most possible economical solution, it relies on the use of traditional construction materials, such as concrete and steel, especially when a relatively large number of buildings needs to be reinforced, in a country with limited economic opportunities, such as Albania.
3. Improves stresses in the wall panels. [they are not cited in this article].
4. The columns are all located in the perimeter, where their realization is more likely to be carried out even in conditions when people live within the dwellings they own.

Conclusion

The study of this building started a long time before 26.11.2019 when Albania was affected by an earthquake of 6.3 Richter magnitude, which caused over 50 victims and a lot of material damage. One of the buildings affected by this earthquake was this kind of building. Therefore, the study and the exact results for the way of improvement of this building is an important task not only of this study but also of other studies that will be undertaken in the future, by other colleagues, in the following.

I think that an important factor in the fact that the periods of this building are high, for the version of brick masonry 25 and 38 cm, or in the version with the layered wall, is the own weight of the masonry!

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