

DESIGN METHODOLOGIES FOR THE ASSESMENT AND RETROFITING OF THE EXISTING MASONRY BUILDINGS

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ABSTRACT

At the present time, in Romania are many old unreinforced masonry buildings, made before the elaboration of the regulations of seismic design. Because some of these buildings are historical monuments and must be preserved and others cannot be taken down because of important reasons (social and economic), it is necessary to protect them to seismic action by different methods of retrofitting.

For this reason, into a technical expert appraisalment, it is made first an evaluation of the seismic vulnerability of the structure, according the procedures stated by the Romanian seismic code P100-92 [6], by comparison between the strength capacity of the structure and the required strength and classification of the structure into one of four classes of seismic risk (RSI-RSIV). The value of the insurance degree and the criteria of the seismic code give the intervention solution over the building.

The choice of the solution must be according to: the destinations given to the building, the seismic conformation and the class of seismic risk. One of the most used solution is the coating of the masonry wall with wire mash of reinforcing steel and cement mortar, applied on manually or by guniting.

In this paper we will present the analysis, by calculation, of a theoretical pattern of structural masonry element, before and after strengthening and also numerical studies.

The calculation method which shall be presented was the object of a number of research studies realized by the authors and it was also tested in experimental labs.

Keywords: Masonry, retrofitting, strength capacity.

1. INTRODUCTION

In the analysis of a masonry structural wall, retrofitting or no, there are considered three conventional deformation stages: cracking (F), yielding in compression (C), ultimate (U). The shear strength is determined at the intersection of the limit curves: the curve corresponding to shear failure and the curve corresponding to failure in eccentric compression stress.

The methodology for the design of unreinforced masonry walls, subjected to in-plane bending, shear and axial force was implemented into a design manual, addressing either new and existing buildings and was presented in a design handbook [2], which can be used for designing new shear walls, for analyzing the shear walls in existing buildings and also for the retrofitting masonry wall.

2. ASSUMPTIONS OF THE METHOD

The assumptions used in the method are presented below.

1. It is accepted that, for structural unreinforced masonry walls, the main failure criterion is diagonal failure, due to shear stresses.
2. The law of Bernoulli applies.
3. The mortar in the bed joints at the bottom part of the wall has null tension strength.
4. The normal compression stresses (σ) have a linear variation on the elastic zones ($\epsilon < \epsilon_c$) of the section.
5. On the plastic zones of the section ($\epsilon \geq \epsilon_c$), the normal compression stresses are constant and equal to the compression strength of masonry (f).
6. The distribution of the shear stresses τ along the height of the section conforms to the average flexural shear stress formula (i.e. is parabolic); the shear stresses are distributed only over the compressed, elastic zone of the section ($\epsilon < \epsilon_c$).

3. THE SHEAR STRENGTH OF RETROFITING MASONRY WALL

In the design of shear strength of the retrofitting masonry wall, the equivalent strength in compression and equivalent resistance to the principal tensile stress is take into account; this equivalent strength includes two safety ratios about:

- interaction between the coating and the unreinforced masonry until the ultimate stage;

- the quality of the materials.

3.1 THE EQUIVALENT STRENGTH IN COMPRESSION

The calculation of equivalent strength in compression of the retrofitting masonry (fig.1) it is determined by the strength of the unreinforced masonry and by the strength of the cement mortar (see formulas 1 and 2).

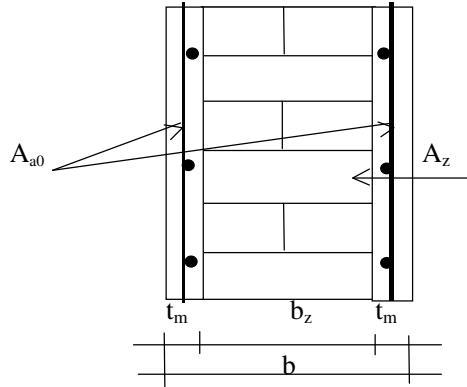


Figure 1. Retrofitting masonry structural wall

$$f^{eq} = c_c [nf + (1-n)f_m] \quad (1)$$

where:

$$n = \frac{A_z}{A_{tot}} \quad (2)$$

f – compression strength of the masonry

f_m – compression strength of the mortar of the coating

c_c – partial safety ratio for the interaction between the two materials: mortar coating and masonry, until the ultimate stage

A_z – the area of the unreinforced structural element

A_{tot} – all the areas of the retrofitting masonry element

b_z – the thickness of the unreinforced structural element

b – all the thickness of the retrofitting masonry element

t_m – the thickness of the mortar coating

3.2 THE EQUIVALENT STRENGTH TO THE PRINCIPAL TENSILE STRESSES

The calculation of equivalent strength to the principal tensile stresses of the retrofitting masonry (fig.1) is determinate by the tensile stress of the mortar of unreinforced masonry, by the tensile stress of the mortar of the coating and the reinforcing bars (see formulas 3 and 4).

$$f_p^{eq} = c_p [nf_p + (1-n)f_{pm}] + 0.8n_a f_s \quad (3)$$

where:

f_p – strength to the principal tensile stresses of the mortar of joints of the masonry

f_{pm} – strength to the principal tensile stresses of the mortar of coating

f_s – tensile strength of the reinforcement steel

c_p – partial safety ratio for the quality of the mortar in the joints :

$$n_a = \frac{A_{a0}}{100b} \quad (4)$$

where:

A_{a0} – area of the reinforcement steel (cm²/m)

b – all the thickness after the retrofitting:

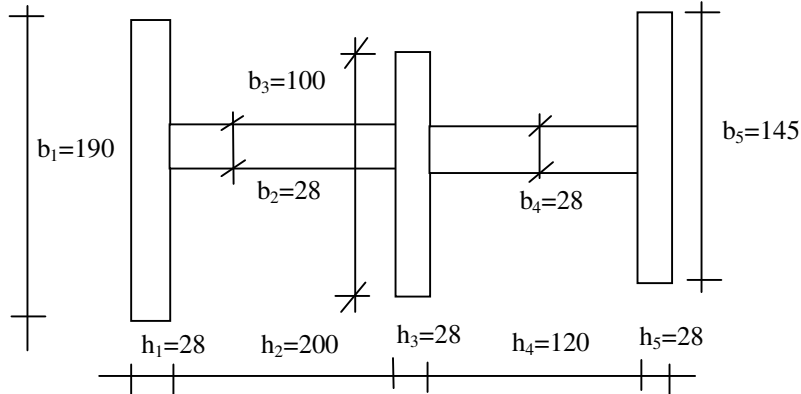
b = b_z + 2t_m – for coating two faces

b = b_z + t_m – for coating only one face

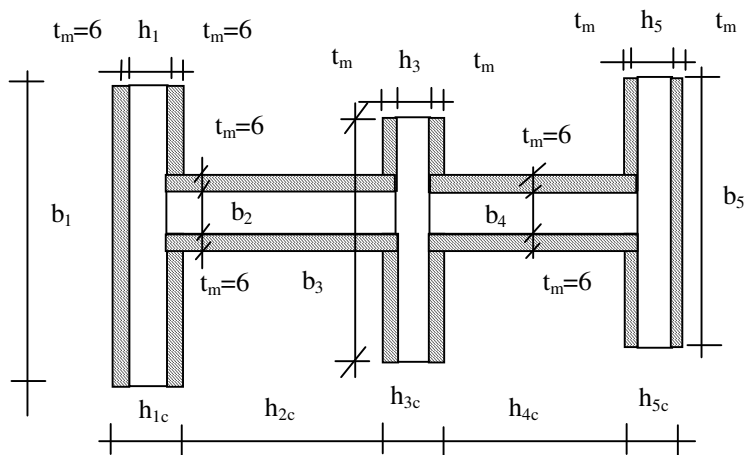
4. NUMERYCAL STUDIES

For the evaluation of the efficiency of retrofitting solution has been chose an multiflanged shape (fig.2) which was calculated with a medium normal compression stress in two variants: unreinforced masonry (fig.2a) and

retrofitting masonry (fig.2b). The characteristic conventional deformation stages of the two sections (F, C, U) can be determined in the same way with the unreinforced masonry [2], the only difference consisting in strength of the materials, determined in the same way as shown above in the chapter 3.



a) Unreinforced masonry structural wall



b) Retrofitting masonry structural wall

Figure 2. Multiflanged section of masonry structural wall a) unreinforced b) retrofitting

There was determined the diagrams of the normal compression stresses (σ) and the shear stresses (τ) correspondent to the conventional stages of deformations (F,C,U) for the unreinforced masonry (fig. 3a) and retrofitting masonry (fig.3b).

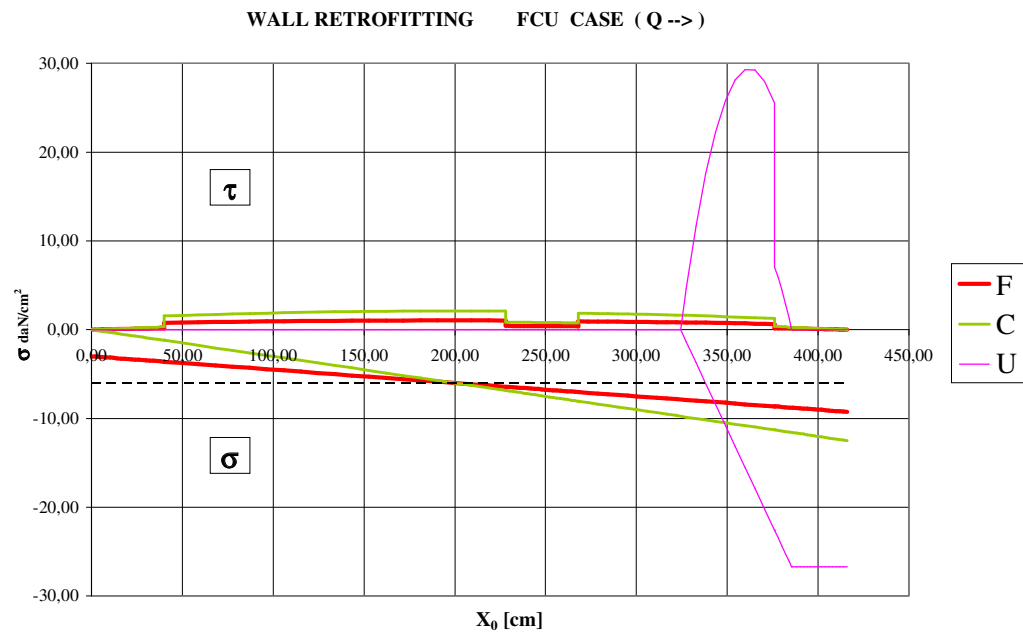
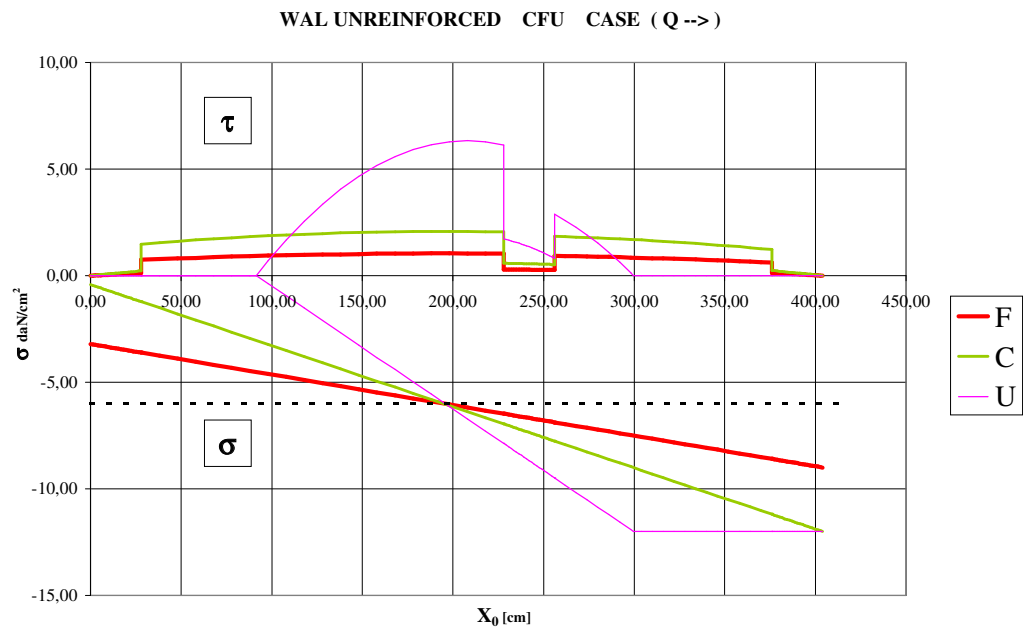
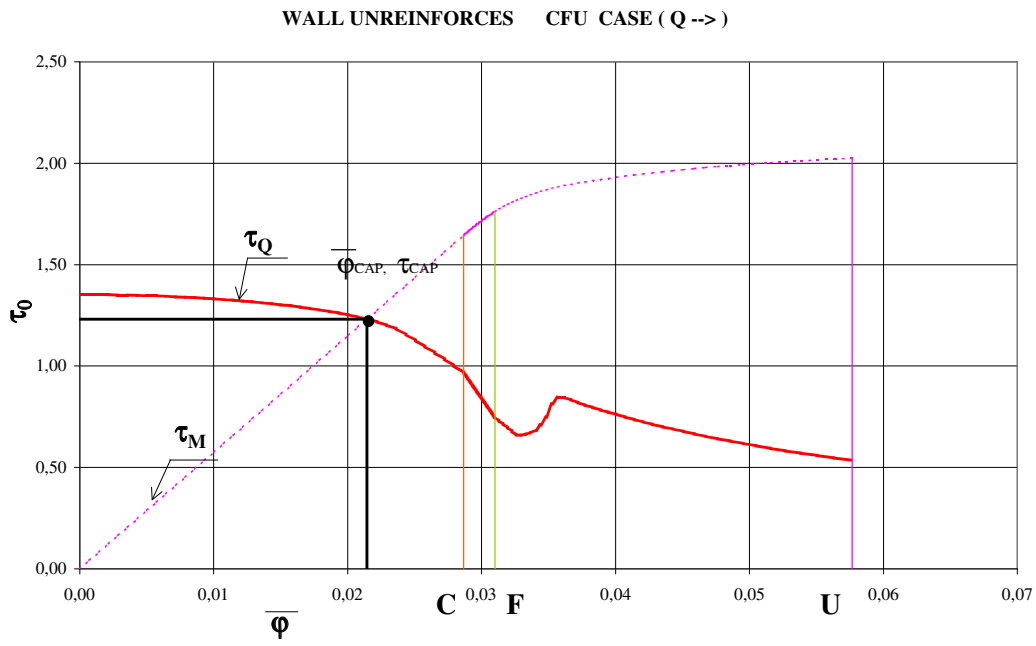


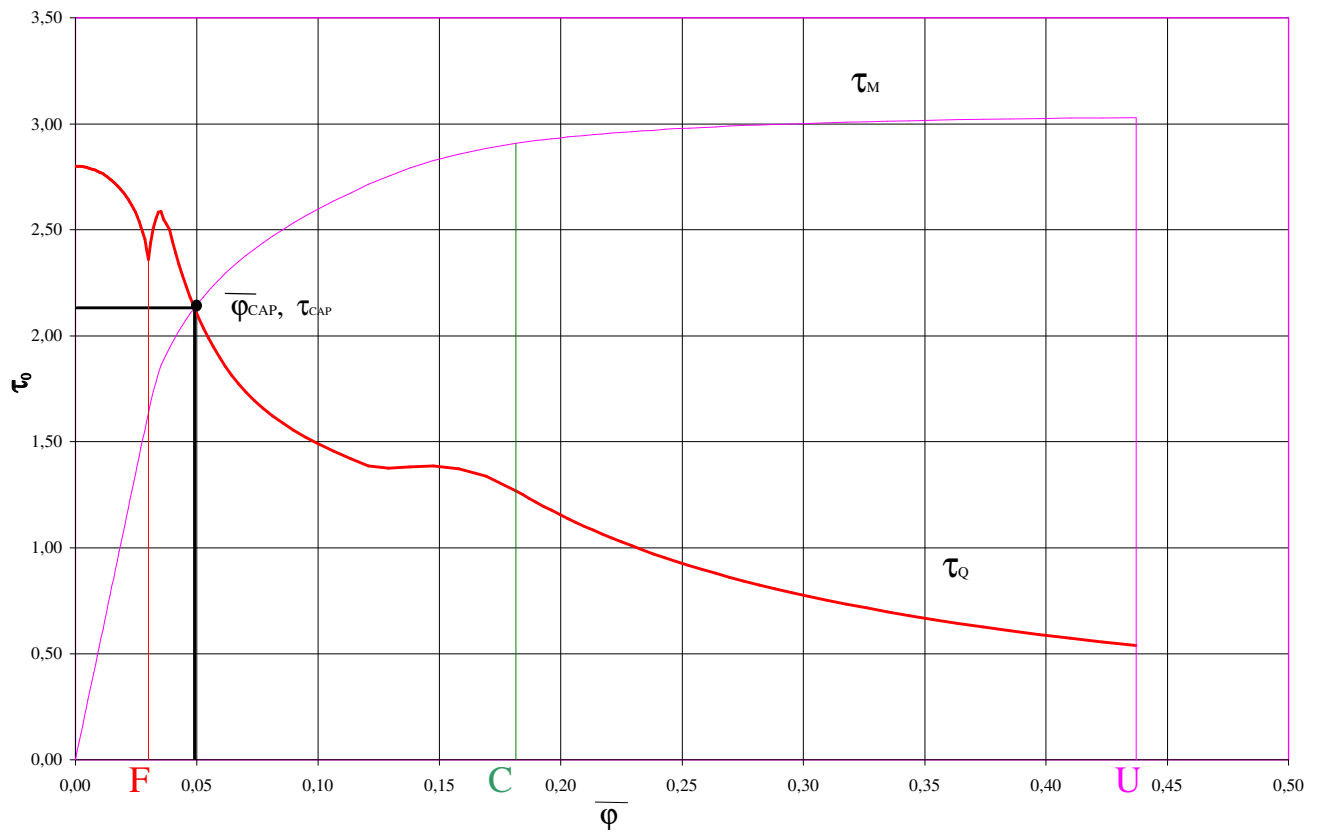
Figure 3. Biographical analysis of the unreinforced (fig. 3a) and retrofiting (fig.3b) masonry

Also was determined the shear strength capacity at intersection of capacity curves as shown above, in chapter 1.



a

RETROFITTING WALL FCU CASE (Q-->)



b)

Figure 4. The values of shear strength, for unreinforced masonry a) and retrofitting masonry b)

5. CONCLUSIONS

The design of equivalent strength of the retrofitting masonry was analyzed into the *Research about the design of the structure of masonry from the seismic risk, for the harmonization with the international prescriptions* [7] and it was tested in laboratories [10], [11]. The results of the tests are comparable with the results of the design. This method is advantageous because the design of the retrofitting unreinforced masonry elements with reinforced mortar cement coating, is made similar with unreinforced masonry elements.

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