Scientific Papers. Series E. Land Reclamation, Earth Observation & Surveying, Environmental Engineering. Vol. IV, 2015
Print ISSN 2285-6064, CD-ROM ISSN 2285-6072, Online ISSN 2393-5138, ISSN-L 2285-6064

COMPARATIVE ANALYSIS OF EFFORTS AND DEFORMATIONS STATE AT BRICK MASONRY PANELS

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Abstract

This article aims to emphasize the deformation state of a masonry wall, for four situations of masonry reinforcement with polymeric grids. Polymeric grids are referred as seismic reinforcement solutions in the following masonry codes: Eurocode 8, and Romanian codes P100 and CR6. Polymeric grids can be used for confinement and reinforcement of masonry with bricks and mortar due to the properties of grids and mortar, and due to the cooperation between reinforcement and mortar that is anchorage.
The masonry is an elasto-plastic material, to which characteristic curve σ-ε strain-deformation has a characteristic aspect. Deformation energy is represented by the surface determined between the σ-ε curve and the axis ε.
The total specific deformation ε corresponding to a compression stress σ can be decomposed in two parts, one elastic εe, which is cancelled after the removal of external action, and the other plastic, remanent, εp.
The case study present a comparative dynamic analysis of deformations state in structural masonry panels (soft diaphragms) in the following situations: plain, reinforce , confined and reinforced+confined masonry with polymer grids.

***Key words**: masonry, deformations, dynamic analysis.*

INTRODUCTION

The masonry is elastic-plastic material, whose characteristic curve strain-stress (σ-ε) has a specific aspect (Figure1).
The total specific deformation ε corresponding to a compression stress σ can be decomposed in two parts, an elastic one ε_e, which is canceled after the removal of external action, and another plastic, remanent ε_p.

$$\varepsilon = \varepsilon_e + \varepsilon_p \qquad (1)$$

The limit specific deformation εlim corresponding to the normalized resistance rn is obtained by integration:

$$\varepsilon_{lim} = \int_0^{R_n} \frac{d\sigma}{E(\sigma)} \qquad (2)$$

$$E(\sigma) = \frac{d\sigma}{d\varepsilon} \qquad (3)$$

where E(σ) is Young's modulus, relative to variable loading step.

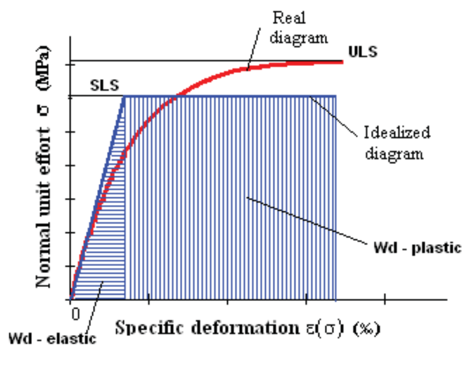

Figure 1 – σ-ε masonry curve

$$W_d = W_el + W_{pl} \qquad (4)$$

$$w_d = \frac{\sigma\varepsilon}{2} \qquad (5)$$

where:
- W_d – deformation energy (J)
- W_el – elastic deformation energy (J)
- W_{pl} - plastic deformation energy (J)
- w_d – specific deformation energy (J/m^3)

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MATERIALS AND METHODS

1.The masonry

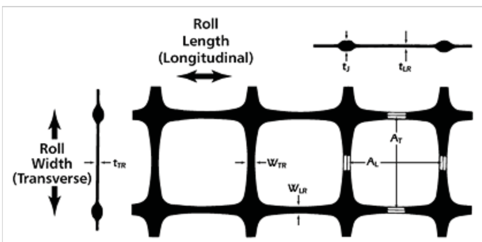
In the state-of-the-art there are two known types of masonry. One type is the original brickwork, composed of burnt soil brick units bonded together with lime mortar. The other type is made of ceramic bricks burnt up to the point of vitrification, using concrete mortar as binder. There are important differences between the two types of masonry, which confer them different properties.

Masonry is reinforced in order to increase its resistance to seismic activity. Original masonry can be armed with non-metallic, polymer-based reinforcements, which works through the anchoring effect.

2. Polymer reinforcement

The current study focuses on the masonry armed or/and confined with polymeric reinforcement grids made under the license of Tensar International Ltd. in UK. These grids fulfill the required seismic reinforcement criteria for strength, strain and stiffness.

The seismic protection method using polymer grids on lime mortar brickworks has been patented in Romania (Sofronie, 1995).



Tensar geogrid - typical dimensions (mm)

	A_L	A_T	W_{LR}	W_{TR}	t_J	t_{LR}	t_{TR}
RG20	39	39	2.2	2.4	4.1	1.1	0.8
RG30	39	39	2.3	2.8	5.0	2.2	1.3
RG40	33	33	2.2	2.5	5.8	2.2	1.4

Grid type	Grid resistance (kN/m)	Specific weight (daN)
RG20	20	0,2
RG30	30	0,3
RG40	40	0,4

Figure 2. The geometrical and mechanical characteristics of polymer grids (source: http://www.tensar.co.uk/)

3. Dynamic calculation

The dynamic calculation was modeled according to the Romanian standard P100-1/2013, in case of the simplified calculation. For this purpose it was considered an earthquake in Bucharest area (a_g = 0.30g, T_c = 1.6 s, IMG = 225 years), in all four previous cases: unreinforced masonry, reinforced masonry, confined masonry and reinforced + confined masonry (Figures 3-10).

RESULTS AND DISCUSSIONS

1. Unreinforced masonry (URM) subjected to earthquake

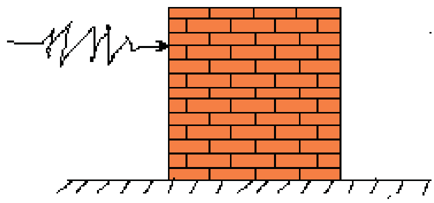


Figure 3. Unreinforced masonry subjected to earthquake

Rc_{URM} = 0.9 MPa – compressive strength URM
E= 0.4 GPa – Young's modulus
G = 0.08 GPa – shear modulus
ν = 0.15 - Poisson's ratio
γ= 18 kN/m^3 – specific weight
ρ = 1834 t/m^3 – volumetric mass density
$\alpha_v = 10^{-5}$ °C^{-1} (sau 10^{-5} K^{-1}) - thermal expansion coefficient
F = Rc_{URM} = 0.9 MPa – applied force

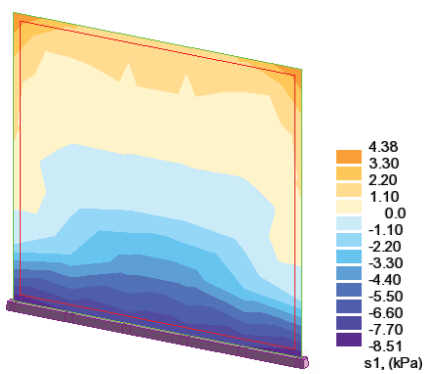


Figure 4. Displacement diagram for unreinforced masonry (T = 0.34s), normal stress ranges (kPa)

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2. Reinforced masonry with polymer grids (RM) subjected to earthquake

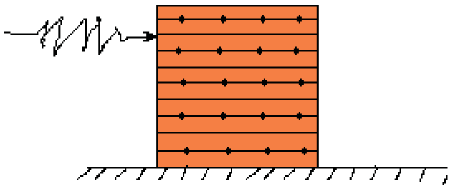

Figure 5. Reinforced masonry in each row with polymer grids subjected to earthquake

Rc_{RM}=1 MPa – compressive strength RM
E= 0.4 GPa – Young's modulus
G = 0.08 GPa – shear modulus
ν = 0.15 - Poisson's ratio
γ= 18 kN/m^3 – specific weight
ρ = 1834 t/m^3 – volumetric mass density
$\alpha_v = 10^{-5}\ ^oC^{-1}$ (sau 10^{-5} K^{-1}) - thermal expansion coefficient
F = Rc_{RM}= 1 MPa – applied force

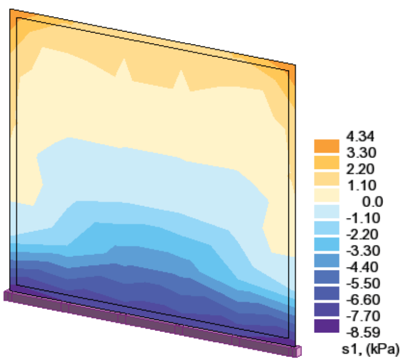

Figure 6. Displacement diagram for reinforced masonry (T = 0.28s), normal stress ranges (kPa)

3. Confined masonry with polymer grids (CM) subjected to earthquake

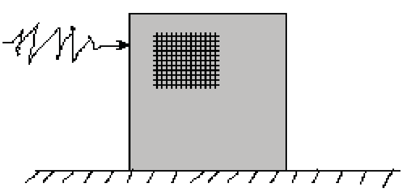

Figure 7. Confined masonry with polymer grids subjected to earthquake

Rc_{CM}=1.06 MPa – compressive strength CM
E= 0.4 GPa – Young's modulus
G = 0.08 GPa – shear modulus
ν = 0.15 - Poisson's ratio
γ= 18 KN/M^3 – specific weight
ρ = 1834 t/m^3 – volumetric mass density
$\alpha_v = 10^{-5}\ ^oC^{-1}$ (sau 10^{-5} K^{-1}) - thermal expansion coefficient
F = Rc_{CM}= 1.06 MPa – applied force

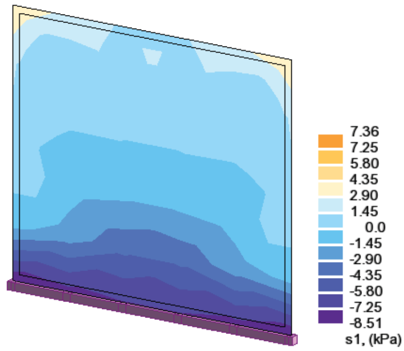

Figure 8. Displacement diagram for confined masonry (T = 0.24s), normal stress ranges (kPa)

4. Reinforced and confined masonry with polymer grids (RM+CM) subjected to earthquake

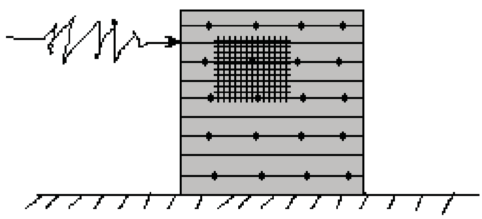

Figure 9. Reinforced and confined masonry with polymer grids subjected to earthquake

Rc_{RM+CM}=1.16 MPa – compressive strength RM+CM
E= 0.4 GPa – Young's modulus
G = 0.08 GPa – shear modulus
ν = 0.15 - Poisson's ratio
γ= 18 kN/m^3 – specific weight
ρ = 1834 t/m^3 – volumetric mass density
$\alpha_v = 10^{-5}\ ^oC^{-1}$ (sau 10^{-5} K^{-1}) - thermal expansion coefficient
F = Rc_{RM+CM} = 1.16 MPa – applied force

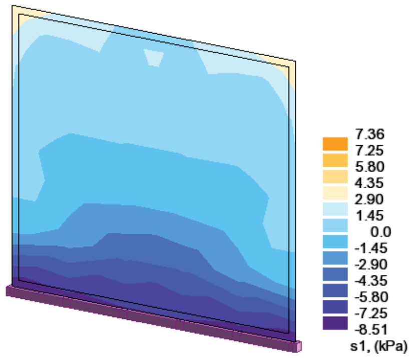

Figure 10. Displacement diagram for confined and reinforced masonry (T = 0.22s), normal stress ranges (kPa)

Tabel 1. Maximum displacements on two orthogonal directions (mm)

unreinforced masonry		reinforced masonry		confined masonry		reinforced + confined masonry	
dir. x	dir. y	dir. x	dir. y	dir. x	dir. y	dir. x	dir. y
0.02	41.2	0.01	27.39	0.01	20.49	0.01	16.41

CONCLUSIONS

1. From the results on y direction, it is noted that, compared to the unreinforced masonry, the maximum displacement of the reinforced masonry wall is reduced by 33.5%, the maximum displacement in confined masonry is 50.3% lower, and reduces by 60.2% for reinforced+confined masonry. Also, comparing the reinforced masonry and confined masonry, the maximum displacement decreases by 25.2%, and in the case of reinforced+confined masonry it decreases by 40.1% comparing to reinforced masonry (Figure 11).

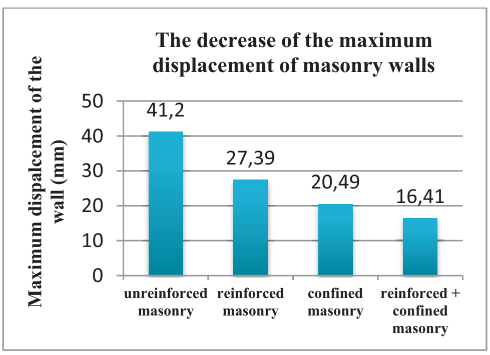

Figure 11. The decrease of the maximum displacement of masonry walls

2. The overall stiffness of the analyzed masonry panel increases by subtracting of the value of the oscillation period (T). Comparing with the unreinforced masonry, the oscillation period of the reinforced masonry decreases by 17.6%, in case of the confined masonry it decreases by 14.3%, and in case of reinforced+confined masonry it decreases by 8.3%. Also, comparing with the reinforced masonry, confined masonry oscillation period decreases by 21.4% and in case of reinforced+confined masonry it decreases by 8.3% (Figure 12).

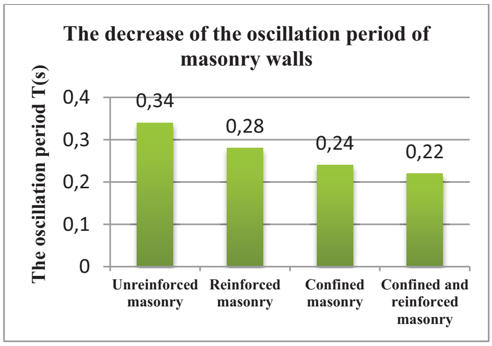

Figure 12. The decrease of the oscillation period of masonry walls

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