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USING POLYMERIC GRIDS IN MASONRY RETROFITTINGS

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Abstract: *The use of composite materials in religious buildings and historical monuments, include two key principles, supported by the Venice Chart (1964), namely: structural interventions are less visible and does not alter the appearance of the building; action is reversible, with the possibility of disassembling initially established in the event of non performance. Composite building efficiency is obtained only by ensuring adequate anchorage length at the ends of the material.*
Keywords: *FRP, polymeric, grid, strength, capacity*

1. INTRODUCTION

In the entire world there is a huge number of existing masonry buildings with masonry structural walls system made of: stones, solid or cored bricks.
Because of their emplacement in the earthquake or mining subsidence areas for a lot of them a retrofitting solution must be adopted as quick is possible.
Generally speaking there are only several retrofitting possibilities such as:
1. A new structural system insertion which to cover the lack of strength capacity and which may be:
a. A confining system with RC small columns and belts
b. A frame system: RC or steel
c. RC structural walls system
2. Retrofitting of the existing structural system using jacketing:
a. In classical solutions: RC coat with steel reinforcements
b. In modern solutions: using FRP and epoxy resins or using polymeric grids and lime mortar

2. MASONRY STRUCTURES MAIN ASPECTS

Normally each type of structures may satisfy two very important demands to offer safety for gravitational and exceptional actions: stiffness through the lateral displacements and strength capacities. From this point of view the buildings with masonry walls structural systems present enough stiffness. As a measure of it the fundamental period of vibration may rise to T=0.05n seconds (where n represent the number of oscillating building levels).
The main characteristic of the existing stock of masonry buildings (without adequate design codes) is that usually the masonry blocks have high strength capacities and the mortars are with a low quality and strength. Thinking to these we may say that the main problem of the existing masonry structures is the lack of strength capacities and not the stiffness. But the masonry as a construction material is a composite material consists in blocks and mortar layers and its strength depend of both components.
Each seismic or mining subsidence zone have proper accelerations and displacements spectra (in function of the recorded data) but almost each one have a period of resonance T_r (highlighted as an exemplification in Figure 1). In function of it, the fundamental period of vibration T of a masonry building may be like in the table 1.
The existent masonry buildings stock consist of ordinary buildings (dwellings for instance) but also from cultural heritage buildings (churches, historical monuments).
Their retrofitting solution is a complex decision because of the functionality and architectural aspects but also for the structural safety. Mostly the RC solution seems to become traumatizing for the buildings. The decision must be in accordance of all these.

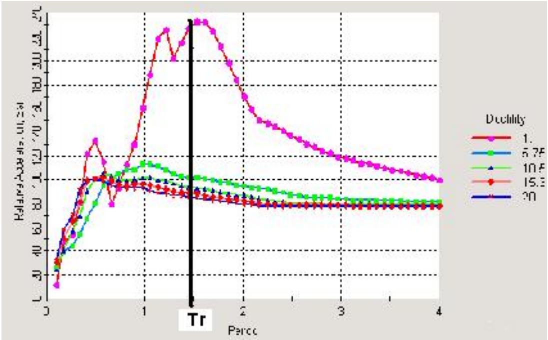

Figure 1 - Equal ductility spectra exemplification

Table 1 Spectral position.

Case	Comparison	Acceleration Spectra value	Stiffness	Drifts
1	T<Tr	minimal	great	small
2	T=Tr	maximal	enough	normal
3	T>Tr	medium	low	large

Usually the architectural point of view is more or less take into consideration by the civil engineer designers but for the cultural heritage buildings, the architects have the principal role. If RC solution are normally chosen for the first category, for the second normally remain just one possibility – to use the modern materials and techniques (FRP or polymeric grids solutions).
We shall ask which one is better to use?
From our opinion, after a lot of tests made for FRP solutions we observed that in the majority of the cases (even it was about stones or clay bricks) an exfoliation of FRP from the masonry surface appear (and this happened into laboratory conditions, well supervised and controlled). Some of these are presented in the figure 2.

Figure 2 - FRP solution after the tests

Whatever, the FRP materials and their application system is expansive and if the final result conduct to this behavior shows that something is not match. A lot of explanations can be but we think about a big difference between the materials characteristics (including Young modulus and strengths).
To change the system is possible after this, but is rather expansive too.
On another hand these are specimens, simply peers easy to retrofit and to manage all the connections between the FRP and the main structure. But there are a lot of places into a real building case where the entire systems become complex and difficult for application.
But is not the case of our article so in the followings we'll try just to highlight why a polymeric grid solution may be better first than a classical solution and second than the modern FRP one.

3. POLYMERIC GRIDS RETROFITTING SOLUTION FOR MASONRY STRUCTURES

More than 90% from the human loss became from their building collapses and huge economic losses appear after major earthquakes.
We shall expect than during a building life a lot of small earthquakes may occur in an year, several moderate or medium earthquake during the exploitation life and the severe earthquakes 2-3 times or never. In the following figures the European seismic (Figure 3), geological (Figure 4) and world (Figure 5) seismic maps are presented.

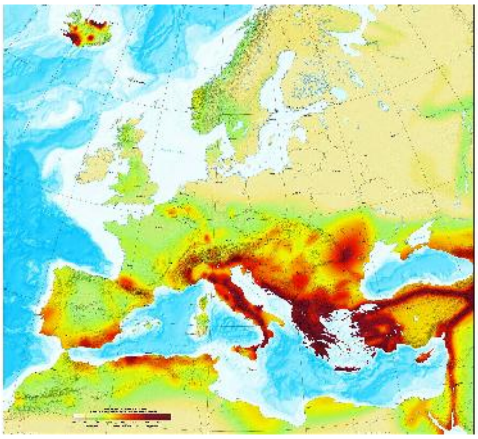

Figure 3 - European seismic hazard map

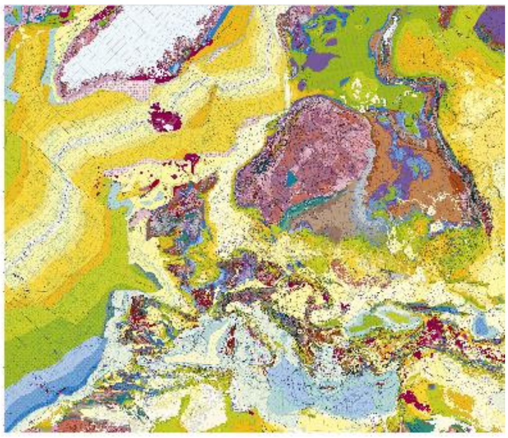

Figure 4 - European geological map

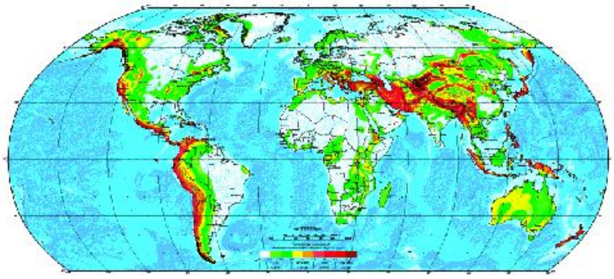

Figure 5 - World seismic hazard map

An alternative solution for the steel nets reinforcement is to use the polymeric grids. For the railways, highways or airports infrastructure the geo-grids were used for over 20 years and if the distance between Brussels and Paris today is cover in a couple of ours this performance is tributary to geo-grids. In the present, for masonry structures three types of grids are available: RG20, RG30 and RG4 (RichterGard system) with the strength capacities of 20, 30 and 40 kN/m. These products are fabricated by former Tensar International Limited from England (named RichterGard in the present) ant having the initial index SS20, SS30 and SS40. It is not possible to use any other type of synthetic product for reinforcement as polymeric grids.
The performances of the grids with integrated joints (made from high density and strength polyethylene) consist in variable and self-reliable strengths ant the capacity for adaptation in case of local stress concentrations resulting energy dissipation inducted in excess. This is coming from the geometrical conformation of those grids and from the macro-molecular structure of the used polymers. All those performances were experimentally granted on the shaking tables or seismic laboratories (Bergamo-Italy, Lisbon-Portugal, Ispra-Italy and Iasi-Romania) for natural scale models of masonry elements or buildings (1D, 2D and 3D-presented in Figure 10-23). In all the cases the results were over expectations and highlighted new and innovative constructive solutions, meaning the homogenization of the reinforced masonry constructions after the elimination of RC structural elements.
The RG new system concept consist in participation of all the masonry strength resources and avoiding the local unitary stress concentrations. In this aim the masonry buildings will be jacketing only on the perimeters, at the external envelopes, with polymeric grids inserted in a simple lime or even lime-cement mortar layer. In some cases also some masonry structural elements may be confined.
Using the RG system the masonry confinement conduct to a reduction of masonry anisotropy and non-homogenously switched by continuous geometrical deflections and to triaxial compression unitary stresses.
The strength capacity of the confined masonry increasing about 5 times as the experimentally tests proves. On another hand, in comparison with the unconfined masonry, for the instantaneously or short term dynamic actions the confined masonry respond in elastic stage, but with a higher dissipative capacity through for the inducted energy.

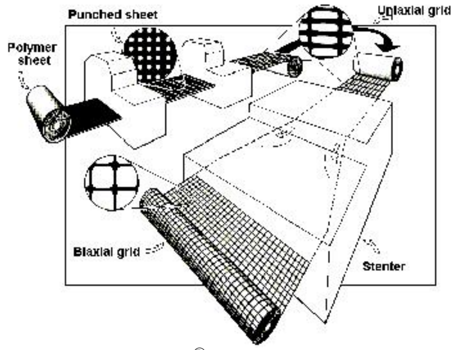

Figure 6 - Tensar® **process**

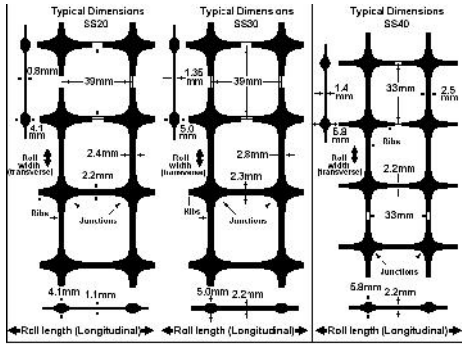

Figure 7 - Geometric Characteristics of *Tensar* Grids

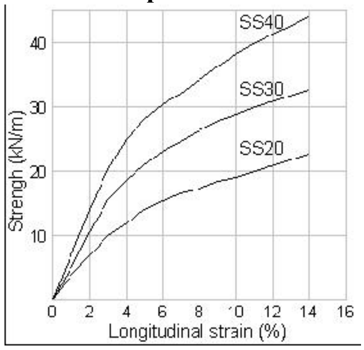

Figure 8 - Longitudinal stress-strain diagram

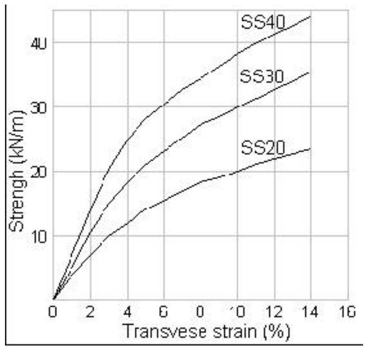

Figure 9 - Transverse stress-strain diagram

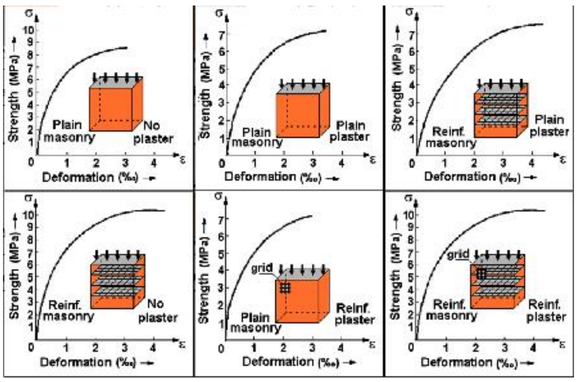

Figure 10 - Wall panels of plain and reinforced masonry/plaster submitted to axial compression

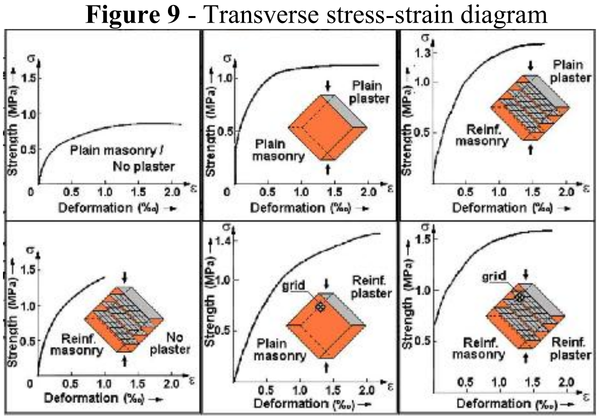

Figure 11 - Wall panels of plain and reinforced masonry/plaster submitted to diagonal tension

All those jacketing solutions previously described are totally integrated to the masonry and no additional structural components which to doubling the columns or the masonry walls. The increasing strengths capacities coming only from the grids and the spatiality of the unitary stresses in the confined masonry.

The RG system keep the original masonry integrity without any other traumas (like cuttings, drillings) and because of its reversibility anytime become easily to take off without to produce any injuries to the initial masonry structures or elements.

Using the polymeric grids jacketing or confinements substitute the RC or steel structural components role. The buildings with confined masonry structures become more homogeneously without any supplementary unequilibrate masses and local stress concentrators, being in concordance with the EC8 (Annex A) requests. In plus, the confinement state for a unitary behavior of the building parts and reduce as called “whiplash” during the seismic actions.

There is a totally difference between the steel reinforcement net fixation and the polymeric grids, in their case the joints anchorage is used. The stress transfer mechanism from the mortar to polymeric grids take place only in the rigid joints through normal stresses (σ), without any tangential stresses (τ) contribution and only the tension efforts are transferred from the mortar to the polymeric grids.

Looking to figures 18 and 19 it is easily to understand that for the solid bricks model with confinement the bricks remain integers and because of the energy dissipation the polymeric grids exfoliate and for the second model with cored bricks the cored brick crushed and the grid remain integer.

Both models stand up after a lot of tests near PGA=1.96g. For the first model, with solid bricks it is easily to remove and replace the grids in safety conditions for the solid bricks masonry but for the second model with cored bricks it is explicit that even the model stand-up this is only from confinement and the crushed bricks cannot be remove and replace. [1] [2] [3] [4] [5]

Figure 12 - Damage patterns for ordinary masonry

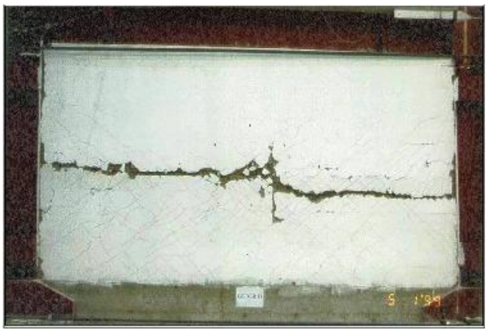

Figure 13 - Damage patterns for confined masonry

Figure 14 - Damage patterns for ordinary masonry

Figure 15 - Damage patterns for confined masonry

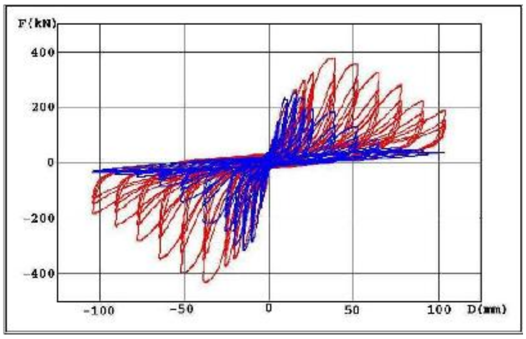

Figure 16 - Comparative hysteretic diagrams for wall panels without openings of plain and confined masonry

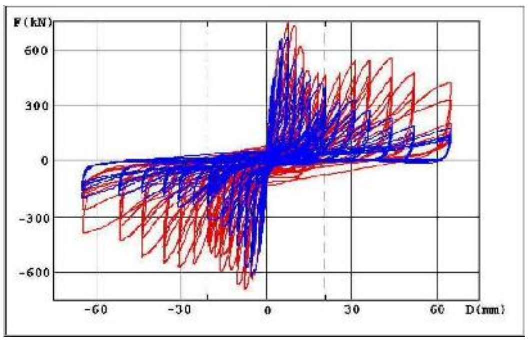

Figure 17 - Comparative hysteretic diagrams for wall panels with openings of plain and confined masonry

Responses on the tested models with confinements

Figure 18 - Failure pattern in Tensar SS20 after 18 dB = 1.96 g

Figure 19 - Failure pattern in Tensar SS20 after 18 dB = 1.96 g

3D – Bergamo Shaking Table tests

Figure 20 - Model 1 – model without confinement

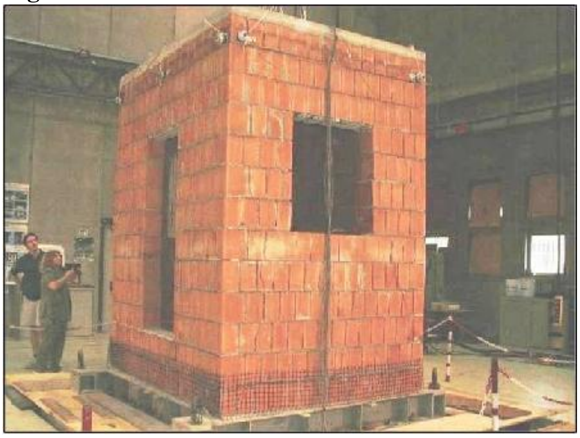

Figure 21 - Model 2 – model without confinement

Figure 22 - Model 1 – model with confinement

Figure 23 - Model 2 – model with confinement

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