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ENERGETIC AND DYANMIC ANALYSIS OF MODERN AND ORIGINAL MASONRY BUILDINGS

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Abstract

The paper aims to emphasize the performance of confined masonry with polymer grids comparing to masonry with steel reinforcement, in terms of energy consumption, strength and stiffness. In the state-of-the-art there are two known types of masonry. The first type is the original brickwork, composed of burnt soil brick units bonded together with lime mortar. The second type is made of ceramic bricks burnt up to the point of vitrification, using cement mortar. 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 reinforced with non-metallic, polymer-based reinforcements, while the modern masonry is reinforced with steel reinforcements. Energy consumption needed to produce a building will be carried out by calculating the embedded caloric energy that includes phases of production and transportation of materials: bricks, mortars and reinforcements. An ergonomic calculation will indicate the mechanical work needed for the construction of the two compared situations: original and modern reinforced brickworks. Increased elasticity and strengthen to earthquake in these two reinforcement situations is shown by a dynamic and modal analysis of structure with adequate software. The analysis will be made on two models taking into account requirement of seismic design code on plane and vertical irregularity.

Key words*: reinforced and confined masonry, polymeric grids, dynamic response, embedded energy.*

INTRODUCTION

Embedded energy is a concept that defines the total energy required to obtain a product, taking into account all stages of production, such as raw material extraction, transportation, manufacturing and commissioning work.
Recently, embedded energy has gained particular importance in respect to reducing the consumption of non-renewable resources in the context of concerns for environmental protection.
From an economic perspective, this concept covers the need to assess the cost of a construction, taking into account that the selling price of construction materials varies according to the manufacturing technology, trade margins and - in addition -the daily fluctuations of currency exchange rates.
Embedded energy is measured as the amount of non-renewable energy per unit of construction material, component or system. It is expressed in megajoules (MJ) or gigajoules (GJ) per unit weight (kg or tonnes) or area (m^2).The process for the embedded energy calculation is complex and involves numerous data sources.
In the present paper we provide a unique study for Romania and Eastern Europe achieved in the conditions of centralized economy, when significant information was available on manufacturing technologies and energy quantities employed, and interest for energy saving was very high.
The study, conducted in the 80th years by the Institute for Building Materials Research and

Design (ICPMC), has determined the total energy embedded in construction materials and products used across the entire manufacturing process, ranging from the raw material extraction to transporting the product to the site (without unloading).

To structure the research, the following were specified: a unique terminology aligned to the one used worldwide, a unique calculation of the caloric energy of conventional fuels, the yield of electricity and other basic parameters and a unified methodology for the analysis of energy consumption for each stage of all technological processes (Georgescu, 1979).

In order to obtain a clearer and more complete information on all the energy involved in carrying out the construction, the indices corresponding to the articles in the inventory indicators C, Iz and Ts have been calculated. Their values resulted from multiplying the normalized specific consumption according to the standardized analysis (quantity of materials, half-finished goods and machine hours per unit of measurement) by the energy indices (Radu, 1980).

As a result, the following average values for the embedded energy of construction materials have been determined (Table 1):

Table 1. The energy embedded in construction materials (Radu, 1980)

Construction materials	Average embedded energy (MJ/m^3)
Ceramic products	
Porous bricks	4253
Pressed solid bricks	4506
Ceramic hollow bricks	5194
Mortars	
Mortar M10 T	3278
Mortar M25 T	2903
Mortar M50 T	2287
Mortar M100 T	2756
Mortar M4 Z	3638
Mortar M10 Z	1873
Mortar M50 Z	2413
Mortar M100 Z	2521
Metal reinforcements	
Rebar	351792
Welded meshes	353518

MATERIALS AND METHODS

Energy embedded in masonry

As a building material, masonry has been used since ancient times as the key component for housing, together with wood and earth.

It is known that since the beginning of construction industry, builders have played an important role in the balance of constructive solutions. If the beginnings consisted mainly in stone masonry solutions for building constructions, today there is a large diversification and specialization in masonry materials.

In masonry, bricks occupy 85% of the total volume while mortar represents 15%. The total amount of primary energy required to achieve a cubic meter of masonry was obtained from the sum of 85% of the embedded energy in bricks with the 15% of mortar energy.

Energy embedded in confined masonry with welded meshes

To improve the performances of resistance, brickwork is reinforced by confinement (jacketing). Networks typically use thin steel bars or welded meshes.

In this study we refer to meshes RΦ4, RΦ6 and RΦ8 (bars of 4, 6 and 8 mm diameter, welded at 10 cm, 15 cm and 20 cm equal distances respectively, across two perpendicular directions) (Figure 2); the specific weight is considered γ_{STNB}=78.5 kN/m^3(Codita, 2011).

Since the lime found in the composition of mortar is known to attack the metal reinforcement by corroding it, for the reinforcing of masonry is used only lime mortar, of type M100 (C17-82 Technical instructions).

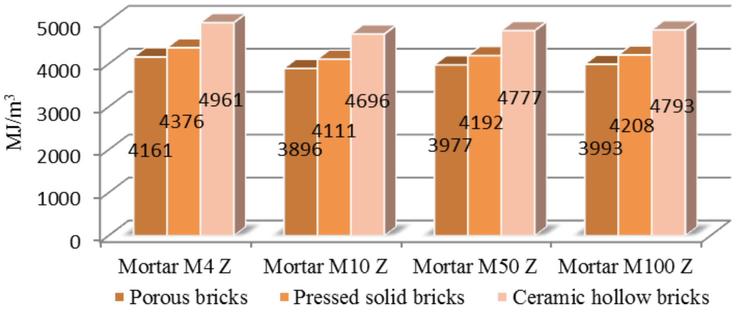

Figure 1. Energy embedded in various types of brick masonry and mortars

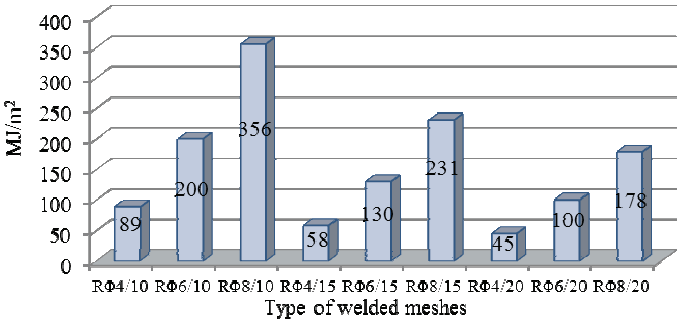

Figure 2.Energy embedded in welded meshes

The metal reinforcement is buried in a layer of 2,5 cm of cement mortar M100 T(Figure 1). The total volume per square meter of concrete reinforced plaster is 0.025 m^3, and the energy embedded in the layer of plaster mortar M100 T is 69 MJ per m^2 (Figure 3).

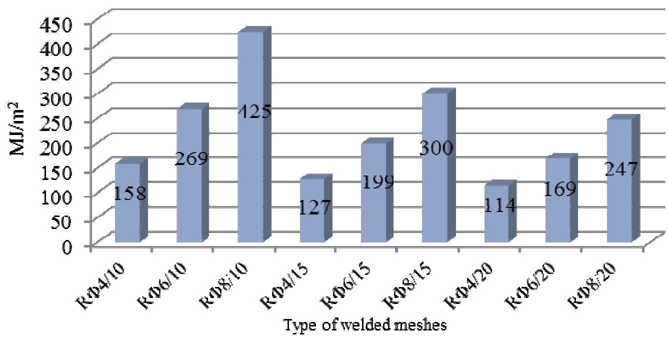

Figure 3. Energy embedded in the reinforced plaster

Polymer reinforcement

As polymer reinforcement three types of grills are used, which are manufactured according to the license held by Tensar International Limited: RG 20, RG 30 and RG 40 (Sofronie, 1995).

Since the TENSAR manufacturer considers the quantity of energy embedded in the polymer grids used in this study to be a trade secret, we have relied on values from other sources (Figure 4). The article "Earth Reinforcement and Soil Structures" by Colin JFP Jones (Colin, 1996), provides information on the amount of energy contained in a tone of high-density polyethylene, but as a membrane (sheet). According to this source, the amount of energy is 84 GJ/tonne or 84 MJ/kg. In order to better represent the manufacturing process, we have added an arbitrary 50% amount of energy, which accounts for punching and stretching (Sofronie, 2004).

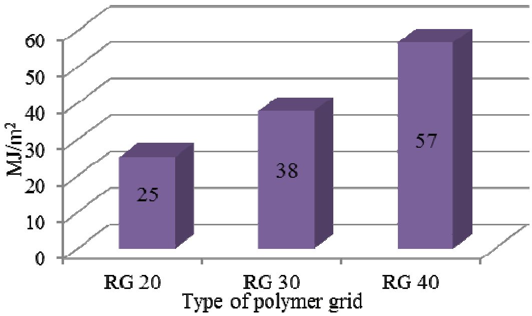

Figure 4. Energy embedded in polymer grid

Energy embedded in masonry confined with polymer grids

Confining with polymer grids is increases the bearing capacity of masonry, by creating a three-dimensional effect. The confinement is applied only on the outer surfaces of masonry and must be fully closed.

The mortar can be lime without cement or lime-cement. A small quantity of cement is needed because in this composite the mortar plays the role of a matrix involved in transferring the stress from the reinforcement to the masonry (only synthetic reinforcement is responsible for the resistance of jacketing).

The minimum thickness of plaster is 18 to 20 mm and can reach up to 30 mm in normal conditions. Thicker plasters increase the weight and raise the cost of construction; besides that, they reduce the interaction between masonry and confinement (Figure 5). One m^2 of plaster requires 0,02 m^3 of mortar.

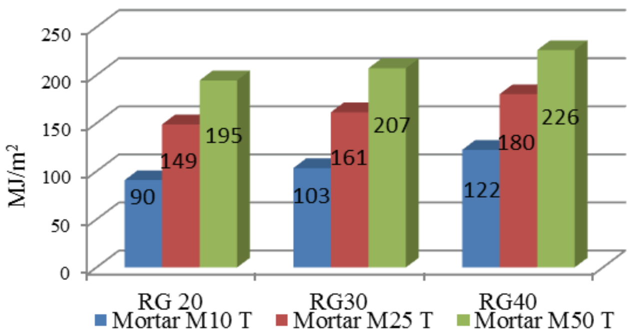

Figure 5. Energy embedded in plaster reinforced with polymer grids

RESULTS AND DISCUSSIONS

Comparative study of embedded energy and seismic response of structures with masonry walls

To model masonry structures, simple and confined, four models have been selected, having the same irregular shape in plan, but with different height regimes (Dragomir, 2012).

A comparative study was conducted for a concrete frame structure with brick panels in three structural variants: simple masonry, reinforced masonry at 4 joints, and reinforced at 4 joints and confined with polymer grids

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(Dragomir, 2009). The table below shows the values calculated for the energy content of perimeter masonry panels (Table 2):

Table 2. Energy content embedded in masonry panels

Height	Masonry (MJ)	Reinforced masonry in joints (MJ)	Reinforced and confined masonry (MJ)
P+3	545356	552716	642988
P+5	818034	829074	964482
P+7	1090712	1105432	1285976
P+9	1363390	1381790	1625870

The final values submitted in the table are influenced by parameters such as: type of bricks (pressed solid bricks), polymeric grids (RG40 for example), plaster mortar (M50 T for confinement and M100Z for masonry) masonry panel thickness (0 30m) and height regime.

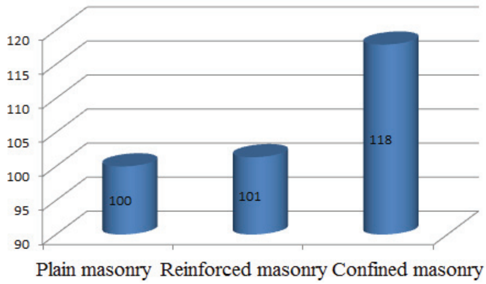

Figure 6. Percentage variation of the energy embedded in the three types of masonry

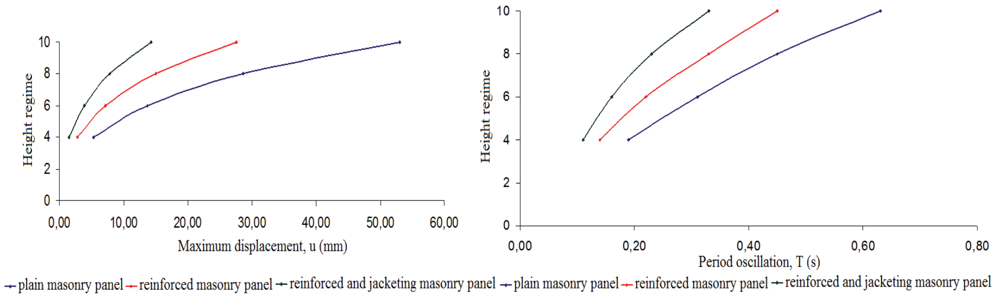

Figure 7. Maximum displacements and oscillation periods obtained by structural analysis

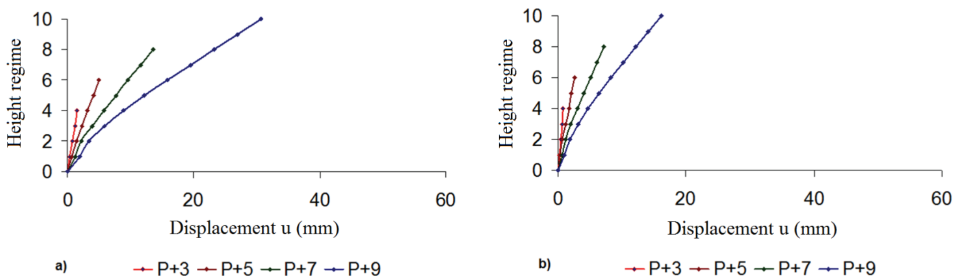

Figure 8. Recorded seismic response of considered masonry types:
a) simple masonry, b) reinforced masonry in joints with polymer grids

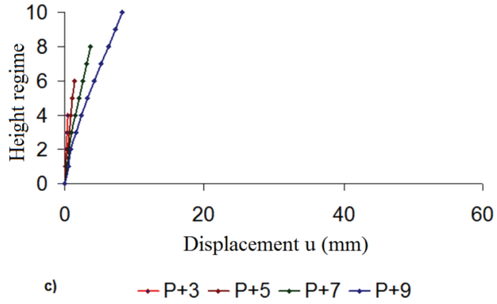

Figure 8. Recorded seismic response of considered masonry types: c) reinforced and confined masonry with polymer grids

The results shown in Figure 6-8 demonstrate the efficiency of polymer grid reinforcements in masonry joints and the influence of polymer grids confinement on masonry walls.

CONCLUSIONS

By comparative energy calculation, the investment required for the development of masonry and confined masonry buildings has been indirectly revealed. According to calculations, RG grid polymeric jacketing is more economical in terms of embedded energy when compared to welded meshes.

The fundamental values of oscillation periods, the displacement values in the nodes of the modelled structures and the upper deformations for each structure have been determined.

In all the considered cases the effectiveness of joints reinforcement as well as of the confinement with polymer grids of masonry panels has been demonstrated.

In conclusion, through the two aspects presented, the energy one and the structural one, the present work has met its objective, to provide a study on the influence of energy embedded in masonry buildings on its structural response.

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