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Natural Stone as Sustainable Resources in Ecological Buildings Design

The paper analyse the heat energy demand and CO_2 emission of one residential building made of natural stone in order to evaluate the advantages in terms of sustainability resulted during operation phase. In this context, it was considered different constructive solution for external walls, optimizing the wall thickness by addition an supplementary layer of natural thermal insulation.

Keywords: *tuff, cork, heat losses, CO_2 emission, saving energy.*

1. Introduction

From ancient time, stones as local natural resources have been mostly used in construction as masonry units for structural and nonstructural elements (walls, fancing and filling material)[1-5].

In the present, the quarring activity is limited, the stone beeing exploitated only for paving, cladding and filler material in cement industry. The volcanic, volcanoclastic (granite, basalt, andesite, tuff), the methamorphic (marble) and the sedimentary (travertine, grainstone, limestone) rocks are the most used in these context.

From all natural stones, the tuff, the grainstone and limestone may also be used as an alternative sollution to artificial masonry units especially for construction of ecological and sustainable buildings.

In Romania, the tuffs and the limestone are frequent occurrences on the border of Transylvanian Basin and of the Carpathians Mountains, in high quantity which can be recovered in building construction field [6].

Regarding the sustainable development of residential building design the heat energy demand and CO_2 emission during the entire lifecycle (manufacturing and construction, exploitation, and demolition phases) should be reduced to minimum as possible. In this respect, the paper analyse the energy demand (kWh/year) for heating and CO_2 emissions (kg/year) of one residential building made of tuff blocks considering three different constructive solutions for external walls.

2. Analysis of heat energy demand and CO_2 emissions

The structure has been design respecting the rules and constructive details provided in Romanian designing codes CR6/2013 [7], P100/1-2013 [8] and Mc001/1,2,3-2006 [9-11].

The buildings taking into consideration are made of unreinforced masonry works with wall thikness of 30 cm blocks of tuff (solution I), 30cm tuff and cork as thermal insulation of 5cm (solution II) respectivelly 10cm (solution III). The attic floor is made of wood with 15cm mineral wool, while floor above the ground is consisting in a slab of reinforced concrete, equaliser layer, thermal insulation and flooring.

The expanded insulation cork board as natural material has been choosen with different thikness (5, 10cm) to keep the ecological aspect of designed building. The thermal conductivity of cork board is between 0.038-0.04W/mK [12].

The geometrical characteristics and thermal caracteristics of envelope members were determined according to the Mc001/1,2,3-2006 [9-11], resulting for wall: Awall= 80sqm, U=1.494 W/m^{2}K (solution I), U=0.446 W/m^{2}K (solution II), U=0.342 W/m^{2}K (solution III); for ground floor: Afloor = 70sqm, U=0.290 W/m^{2}K (solution I, II,III); for attic floor: Afloor = 70sqm, U=0.176 W/m^{2}K (solution I, II,III).

The heat losses in kWh/year through the envelope members is presented in the figure 1.

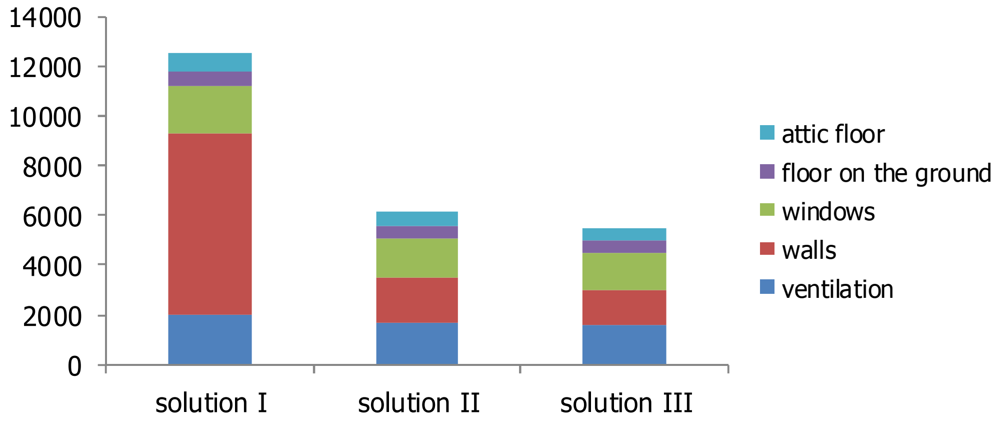

Figure 1. Heat losses (kwh/year) through the building envelope members

From thermal analysis (Figure 1) it result that in the first and second solutions the heat losses are greater through the walls and ventilation while in the third case the heat losses are greater through ventilation and windows.

The heat losses through the walls in the first solution is with 75% higher than solution II respectivelly with 81.6% than solution III, resulting the unefficiency of wall made of tuff stone without thermal insulation layer. To obtain the minum value of thermal resistance, imposed by Mc001/1,2,3-2006 [9-11] the thikness of the walls should be at least 90cm, which makes the building unefficient to seismic action and from cutting, transport and execution point of view. The masonry mortar and rendering based on portland cement materials, should be avoided to prevent the microstructural degradation of tuff stone due to their mineralogical incompatibility. From mineralogical point of view tuff stones contains feldspar, zeolites and quartz which can interact with mineralogical compound of the cement (transformation of feldspar into zeolites or clay, quartz grain corrosion).

Considering the heat losses thorough ventilation it can be seen that values obtained for first solution is higher with 19.9% than third and 17.02% than second solution.

The heat energy requirement for each month (kWh) per each solution is presented in Figure 2.

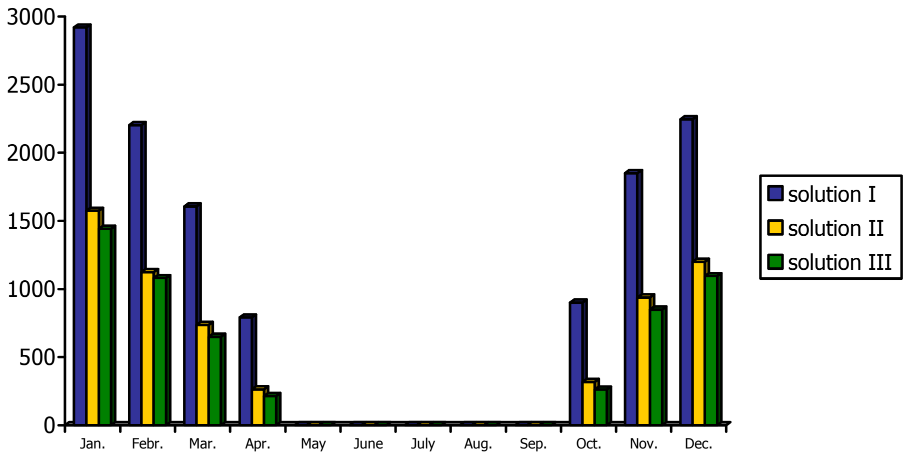

Figure 2. Annual space heat requirement (kwh/month.year) for all three solutions

The total annual space heat requirement for buildings is 63.87kWh/m^3 year and 12519kWh/year (solution I); 31.41kWh/m^3 year and 6156kWh/year (solution II); 28.21kWh/m^3 year and 5528kWh/year (solution III).

The comparison between the results of saving energy in the second and the third solution show a difference of only 10.18%, due to the thickness of cork insulation which improve the thermal characteristics of walls, in this circumstances the heat losses beeing assigned to other building envelope members.

Considering the space heat requirement for buildings was determined the quantity of gas used for heating (Figure 3).

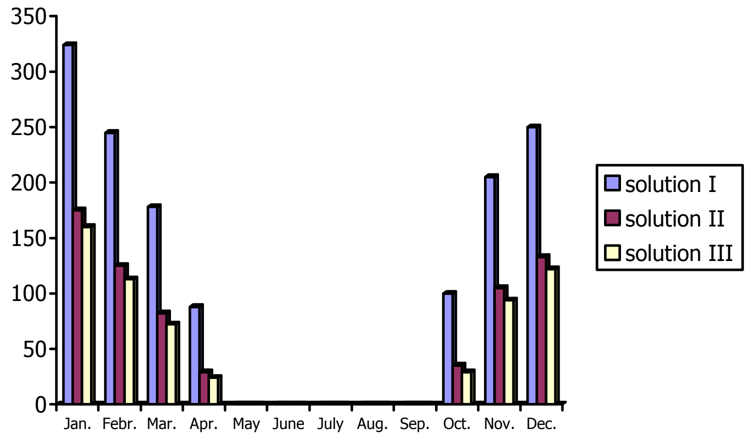

Figure 3. Heat energy demand (mc/year) for buildings

The CO_2 emission in kg/month was determined according to Mc001/1,2,3-2006 [9-11] for all analysed solutions (Figure 4).

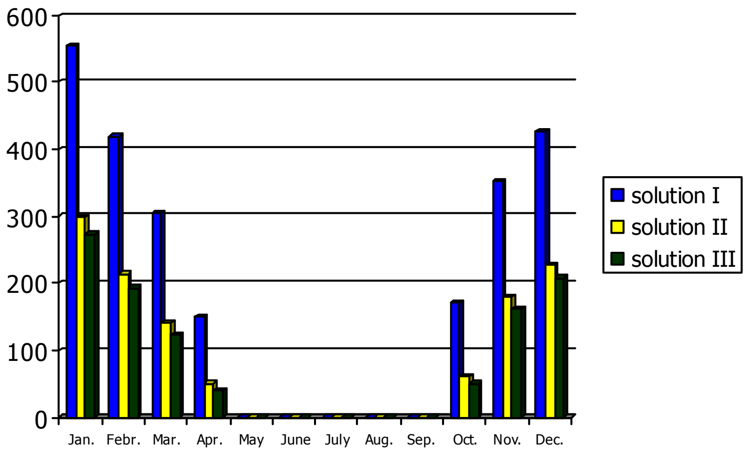

Figure 4. CO_2 emissions (kg/month.year) for all three solutions

From analysis it result that saving of CO_2 emission is 1,261tCO_2 /year (solution II) respectivelly 1,374t CO_2 /year (solution III) compared with the value obtained in the first case. Reporting to the entire operating phase of the building for 50 years, the saving energy and CO_2 emission is about 63.05t CO_2 for the second solution respectivelly 68.70 tCO_2 for the third.

3. Conclusion

The study perfomed in this paper shows that the natural stone may be used for masonry walls in designing the green/sustainable and ecological buildings, but only with thermal insulation. The thermal insulation should be with lower thermal conductivity and eco-friendlly (sheep wool, cork, hemp), in order to reduce the weight and to improve the thermal performance of the entire building. In terms of energy saving and CO2 emissions, the most efficient solution of the solution analyzed is third, with tuff and 10cm of cork. The thermal insulation is recomandable to be placed at the internal face of the wall in order to keep the architectural aspect of the tuff.

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