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Energy performance evaluation of clay bound buildings

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Abstract: The building industry is a dominant energy consumer during the life cycle stages. In recent years, there is a growing interest in energy performance evaluation of buildings. This paper evaluates the energy performance of a residential building in 4 different cases (with different structure materials: perforated ceramic blocks, autoclaved aerated concrete blocks, wooden framework and clay bound). The energy performance of the buildings is studied with the software DosetPEC which has an agreement of Romanian government in that field, and uses the characteristics of the building to estimate the annual energy consumption and the CO2 emission and to elaborate the Energy Performance Certificate. Although the values for the energy performance are similar due to good thermal resistances, the best performance is obtained by the clay bound structure.

Keywords: energy performance, annual energy consumption, CO2 emission, life cycles, environment protect, clay bound building materials

1. INTRODUCTION

One of the biggest problems of the XXI[st] century that needs to be solved is reducing the environmental problems that appeared during the industrial development in the past century [1].

Energy performance has become a major point of interest in the construction of buildings and environmental protection [2]. The energy performance of a building is the energy consumed or estimated to meet the needs related to normal use of the building, necessities that include: heating, hot water for consumption, cooling, ventilation and lightning. The energetic performance of a building is determined according to a methodology and is expressed by one or multiple numeric indicators which are calculated taking into account the thermal insulation, technical characteristics of the building and installations, design and location of the building in relation to external climatic factors, sun exposure and influence of neighbouring buildings, its own sources of energy production and other factors, including indoor climate of the building that influence energy requirements [3].

The purpose of energetic certification is the evaluation of energy performance of a building and identifying solutions to improve these performances.

The selection of suitable building materials has become a major factor in building design and energy performance, which requires analysis of a wide range of parameters, including environmental ones, but after more than 50 years of research the building sector is still responsible for many harmful issues [3]. The principle problems of building industry are the pollution of soil, water and air resulting from unsustainable use of massive amount of raw materials [4]. The construction industry is responsible for depletion of 40% stone, gravel and sand; use of 25 % wood; and for consumption of 16 % fresh water every year [4,5].

In 2010, the building sector signified about 25% of the total final energy consumption in the world, the third largest after industry (32%) and transport (31%) [6,7]. Although this ratio is expected to decrease, building construction will still account for 20% of the total final energy demand in the upcoming years. Space heating and hot water for consumption production are key applications in this sector: 53% for space heating and 16% for hot water for consumption [6,7].

The European Council of March 2007 emphasised the need of increasing energy efficiency in the Union by reducing with 20 % the energy consumption, decrease of CO_2 emissions by 20 % and increase the share of the renewable energy resources to 20 % by 2020 [8].

Since 2005, the Energy performance certificate became mandatory in Romania by Law 372/2005, for new buildings, buildings that are sold and buildings that are for rent [3].

The Energy performance certificate is a mandatory document for all new buildings and is issued based on an energy audit, for a period of 10 years. According to the Ministry of Regional Development and Public Administration from Romania, building owners will no longer be able to sell or rent the buildings without the energy certificate. Based on the certificate, the building receives a grade, that will show that the building is energy efficient, and the grade received can determine the price of the space that will be sold [3].

The grade given to the building is shown on the first page of the certificate, along with the annual energy consumption of the building and the CO_2 emission. The smaller the energy consumption is, the building is more efficient energetic.

The energy performance can be analysed with different softwares that based on the characteristics of the building, will evaluate the annual energy

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consumption and the CO_2 equivalent emission. Based on the results given, the building will receive a grade from 20 to 100 (20 for a building with a high consumption value, and 100 for a building with the lowest consumption value) to emphasize the energetic performance of the construction.

To improve the energy efficiency, the thermal insulation of buildings plays an important role. To achieve a high thermal insulation resistance, new insulation materials and solutions with low thermal conductivity values are being developed continuously, in addition to using the current traditional insulation materials in increasing thicknesses in the building envelopes [9].

This paper analyses the energy performance of a building in 4 different cases (with different structure materials). The first 3 materials selected for the building, are among the most used materials for constructions in Romania for family houses (perforated ceramic blocks, autoclaved aerated concrete blocks, wood framework) and we propose for the fourth type, a recent rediscovered material (clay bound with a low thermal conductivity).

Clay has been recently “rediscovered” as an ecologically sound and healthy building material. Throughout Europe, internationally, and particularly in developing countries, clay is now seen as a deal in building materials for the future. Soil has been used as a building material for thousands of years. Almost a third of the world’s inhabitants live in houses made of soil [10]. Clay is one of the most abundant natural resources of the planet. It covers most of the floors of the ocean and is common on land [11].

This work investigates and compares different properties, requirements and possibilities for traditional and rediscovered thermal building insulation materials and solutions.

2. DESCRIPTION OF THE EVALUATED BUILDINGS

The building studied in this article is a one storey residential building that has no basement, a total useful (heated) area of 99.5 m^2 and a heated volume of 298.4 m^3. The building is suitable for 3-4 persons.

We studied a building (family house) with the same geometrical characteristics, same architectural plans, but with 4 different structural materials for the walls and ceiling. For all the buildings studied, the under-work and the roof structure are the same. The infrastructure consists of continuous reinforced concrete foundations under the walls, reinforced concrete base plate insulated with extruded polystyrene and wood framework with ceramic tiles for the roof. We used different materials for the walls, ceiling and thermal insulation.

In order to represent the energy performance of the building studied, standard material compositions and a rediscovered material composition were selected for the evaluation.

The building with autoclaved aerated concrete walls (Type B) and the building with clay bound walls (Type D) don’t require thermal insulation with other materials due to the good thermal properties of the materials.

The window frameworks were made of PCV with double glazing with the same thermal properties.

For Type A and Type B, we proposed a heating and hot water for consumption system with natural gas, and for Type C and Type D, a heating system with wooden products. Although the software is fitted with ventilation and cooling modules, the building isn’t fitted with these systems.

The next structural solutions were considered:

Type A: Masonry structure of 25 cm thick perforated ceramic blocks and 10 cm thick expanded polystyrene insulation; the ceiling is made of a 13 cm thick RC slab and 20 cm thick mineral wool insulation.

Type B: Masonry structure of 35 cm thick autoclaved aerated blocks; the ceiling is made of a 13 cm thick RC slab and 20 cm thick mineral wool insulation.

Type C: The structure is composed of a wooden framework, 5 cm expanded polystyrene on the outer side, 1.5cm OSB panel, a 10 cm thick mineral wool insulation and gypsum plasterboard on the inner side; the ceiling is made of wood beams and 20 cm thick mineral wool insulation.

Type D: The structure is made of 60 cm thick clay bound walls; the ceiling consists of wooden beams with 15 cm thick mineral wool insulation and clay layer.

The floor plan of the building is represented in the Figure 1. All the materials used for the houses are presented in Table 1

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3. METHODOLOGY

For this study, we analyze the energy performance with the software DosetPEC, that based on the characteristics of the building, will give the building a grade, the annual energy consumption and the CO_2 emission.

The DosetPEC software has approvals of Romanian government to study the energetic performance of buildings and elaborate the Energetic Performance Certificate. The software uses all

Romanian Standards from this field which are according to European Norms.

The input data required by the software consists in: useful (heated) area, heated volume, area of the base plate, areas of the walls by cardinal orientation, area of the windows by cardinal orientation and area of ceiling. The stratification of each element was required to determine the thermal resistances and also a coefficient which reduces the resistance depending on thermal bridges. The heat produced by house equipment like TV, refrigerator, washing machine is not taken into account.

The main property of a thermal building insulation material or solution is the thermal conductivity, where the goal is to achieve the lowest thermal conductivity as possible for the materials used in the building [9].

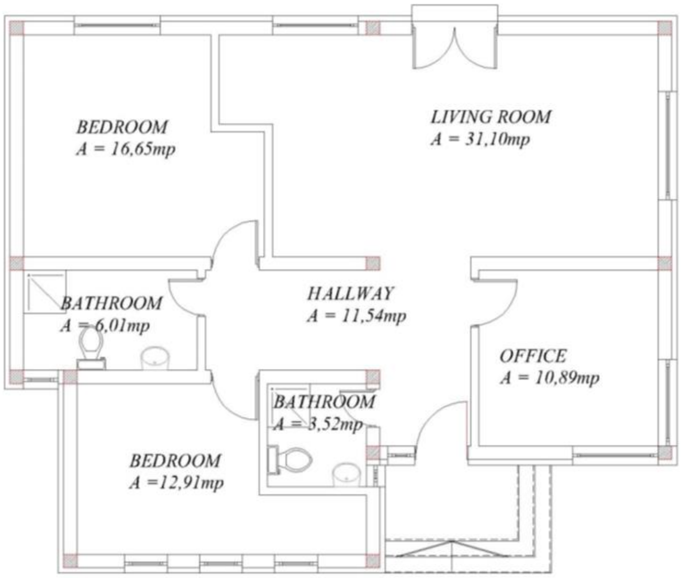

Figure 1. Floor plan.

Table 1. Material and structural elements of the assessed buildings

	Type A **Masonry structure with perforated ceramic blocks**	**Type B** **Masonry structure with autoclaved concrete blocks**	**Type C** **Wooden framework**	**Type D** **Clay structure**
Infrastructure	- reinforced concrete foundation - concrete base plate reinforced - PCV foil - gravel - extruded polystyrene - concrete screed	- reinforced concrete foundation - concrete base plate reinforced - PCV foil - gravel - extruded polystyrene - concrete screed	- reinforced concrete foundation - concrete base plate reinforced - PCV foil - gravel - extruded polystyrene - concrete screed	- reinforced concrete foundation - concrete base plate reinforced - PCV foil - gravel - extruded polystyrene - concrete screed
Vertical walls	- 25 cm perforated ceramic blocks - lime cement plaster - 10 cm expanded polystyrene	- 35 cm autoclaved aerated concrete blocks - lime cement plaster	- wood framework - gypsum plasterboard - 10 cm mineral wool - OSB - 5 cm expanded polystyrene	- 60 cm clay bound - clay plaster
Partition walls	- perforated ceramic blocks - lime cement plaster	- autoclaved aerated concrete blocks - lime cement plaster	- wood framework - gypsum plasterboard	- clay bound - clay plaster
Ceiling	- reinforced concrete beams - reinforced concrete slab - lime cement plaster - mineral wool - concrete screed	- reinforced concrete beams - reinforced concrete slab - lime cement plaster - mineral wool - concrete screed	- wood beams - gypsum plasterboard - mineral wool - OSB	- wood beams - gypsum plasterboard - mineral wool - OSB - clay layer
Roof	- wood framework - ceramic tiles	- wood framework - ceramic tiles	- wood framework - ceramic tiles	- wood framework - ceramic tiles

For all the buildings, the thermal resistances of the elements exceed the minimal thermal resistances required (4.5W/m^{2}K for base plate, 1.8W/m^{2}K for exterior walls, 0.77W/m^{2}K for windows framework and 5W/m^{2}K for ceiling) given in the Romanian Normative C107-1/2011 [12].

To determine the annual energy consumption and the CO_2 emission, the software also requires introducing the main characteristics of the following installations: heating, hot water for consumption, cooling, ventilation and lightning.

Depending on the condition of the materials and installations, penalty coefficients were accorded that reduce the grade given to the building.

4. RESULTS

The annual energy consumption and the CO_2 emission estimated by the software for each of the 4 cases are presented in Table 2.

Table 2. Annual energy consumption and CO_2 emission

	Heating and hot water for consumption system	**Annual energy consumption [kWh/m^{2}an]**	**CO_2 emission [kg$_{CO2}$/m^{2}an]**
Type A	Local system with natural gas	183.1	36
Type B	Local system with natural gas	179.1	35
Type C	Local system with wooden products	180.5	7
Type D	Local system with wooden products	175.6	7

In the next figures, we represent the annual energy consumption and the equivalent CO_2 emission for each structural type.

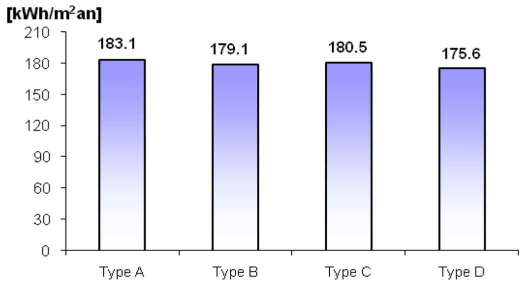

Figure 2. Annual energy consumption.

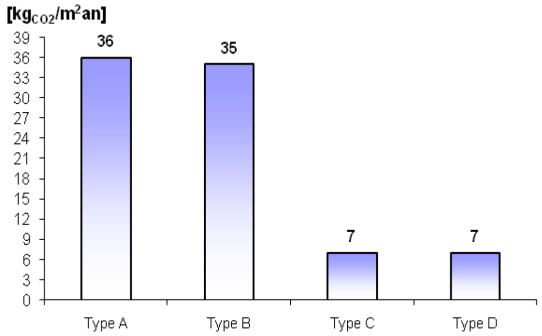

Figure 3. CO_2 emission.

In the next figure we represent the energy consumption for each facility that the building is equipped with. We can see that the highest energy consumption for each building is given by the heat installation.

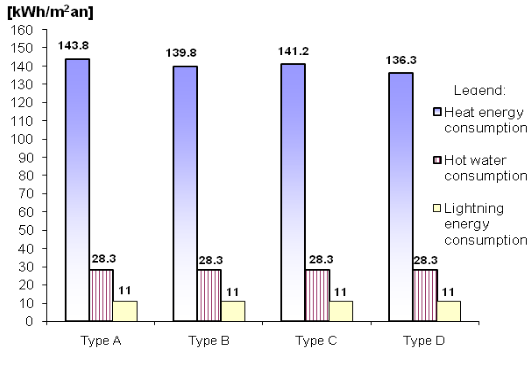

Figure 4. Energy consumption by installations.

5. DISCUSSION AND CONCLUSION

Energy performance is been evaluated for a building in 4 different cases – with four different materials for the structure. The essential issues that are studied are the annual energy consumption and the equivalent CO_2 emissions.

From the study results, we can see that the values of annual energy consumption of the buildings are around 180 kWh/m^{2}an (Table 2, Fig. 2), because the elements of the buildings have similar thermal resistances.

The values of annual energy consumption can be reduced if we take supplementary architectural measures to increase the quality of materials used, better thermal insulation and to use regenerative sources (solar energy, geothermal energy, etc.) to produce energy which will prevent heat loss.

From Figure 4 we can see that the heat energy consumption of the buildings is around 75% from total consumption. **This situation tells us that we can work from the beginning at architectural design to decrease this consumption.**

The most efficient energetic building is the one with clay bound walls - Type D according to design requirements (Table 2), although the walls of the building didn't require thermal insulation. This is due to a low thermal conductivity for clay bound.

We can also observe from Table 2 and Figure 3, that if a heating and hot water for consumption system with wooden products is used, the CO_2 emission is lower than the heat system that uses natural gas as fuel.

The CO_2 emission will decrease with 80% when we use wooden products versus natural gas to produce heat and hot water for consumption. This is important in actions for protecting the environment.

It can be seen that if we improve the energy consumption of a building, this would have a major impact on the total CO_2 emissions.

Finally, we can say that:

- The architectural designers can propose the use of materials with good thermal insulation properties to increase the thermal resistance of the building envelope and to use equipments that are based on renewable energy.
- The use of heating systems with wooden products is a better solution to decrease CO_2 emission and to protect the environment.

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