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STUDY OF THERMAL PERFORMANCE OF PREFABRICATED LARGE PANEL BUILDINGS

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Abstract

Many countries in Eastern Europe, during the 1960–1970s, as well as Albania responded to the growing demand for new houses utilizing the emerging trends for industrialization of the construction process and mass construction of prefabricated residential buildings based on large-panel prefabricated RC elements. During the 1970s large-panel buildings spread throughout the country and became the main type of construction in the Albanian cities such as Shkodër, Tirana, Durrës, Elbasan, Berat, etc. Most of these buildings have five or six stories and comprise different modules, the number of which depended on the urban and architectonic projects.

The construction technology of these types of buildings included only the construction with prefabricated reinforced concrete material and did not take into account the energy performance of these structures. Since the moment of construction, only in the last year, several interventions have been made in different cities where a layer of polystyrene has been placed on the external walls of these buildings in order to enhance their termal insulation.

The aim of this paper is to improve the thermal performance of these buildings by introducing a comparison of their initial situation as they are today and how their performance would be if innovative technologies and materials will be applied. The study is going to analyse the thermal performance of the existing buildings, by means of thermal camera in the city of Kamez, located in Tirana, which has been chosen as a key study. Futhemore, the data obtained from MEEC application are gethered, in oder to compare the previvious, the existing situation and the proposed intervention. The results may be used by municipalities of different cities, not only in the Albanian contex, either where interventions have been made to improve their performance, or for municipalities where thermal regulation policies that have not been yet implemented to these types of buildings.

The existing situation of the buildings according to the calculations, showed a poor thermal performance, regardless of the fact that they are already equipped with thermal insulation building envelope. They have to be requalified in order to be categorized as a buildings with high thermal performance.

Keywords: prefabricated buildings, heat flow, building termal performance, materials of construction; thermal regulations

1. Introduction

Energy efficiency in buildings is one of the main strategic pillars in various EU strategic energy documents. The reason is pragmatic, based on the fact that 40% of total final energy consumption at EU level is consumed in buildings. In addition, traditional and conventional heating systems are mainly based on fossil fuels and thus contribute a large part of CO2 emissions [1].

The thermal performance of different buildings in Albania has been studied by several different authors. The most studies have been done for different building typologies, especially for masonry buildings built around the 70-80s where their performance does not result in the right conditions as mention on a Marku's A. phd thesis [2].

Precast buildings are an assembly of different elements which are prefabricated in the fabric and connect with each other in the construction site by simple connection between them. The simplicity of the connection and the short time of prefabricating the panels and the assembly of the elements has made these types of structures quite popular in Albania, in the region and in the world.

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Many other Eastern European countries, as well as Albania responded to the growing demand for new housing during the 1960s and 1970s by taking advantage of the emerging trends in the industrialization of construction processes and the mass construction of prefabricated dwellings. The buildings were built according to standardized formwork approved by the Albanian government authorities and thus represent standardized techniques widely used in Albania. In the 1970s, large-scale buildings spread across the country and became the main architectural style in Albanian in cities such as Shkoder, Tirana, Durrës, Lushnjë, Burrel, Elbasan, Berat, Pogradeci, Laç, Lezhë, Korçë, Tepelenë, Gjirokastër. The process was automatized and they were fabricated in a new plant near “Josif Pashko" which uses Chinese technology with 2000 apartaments per year capacity. These types of buildings with a residential function make up about 5% of the total residential apartments [3].

After World War II, the major problem was the housing of the population, as a result of the destruction of cities by the Second World War. The very first dwellings that were built were realized with voluntary contribution with blocks and temporary materials to solve the immediate needs. The neoclassical Russian school showed its character in this period with stable and mega buildings constructions. The architectural arguments were gigantism and ornament. However, in terms of appearance, these apartments were characterized by truncated and uncomfortable living space. Meanwhile from the urban and architectonic point of view, their placement in the plan created original squares in function of the community. The standardization of building elements were implemented by the development of the building materials industry. This strategy greatly facilitated the typification of dwellings by unifying the design elements. In the late 1960s and early 1970s, such schemes were strictly criticized for compositional solutions that promote antisocial behavior, for the social effects of expropriations, denying the city's construction tradition. During the late 1980s, the regime of that time managed to radically transform the vast majority of Albanian cities. During these years, large residential blocks were realized, at minimal cost (prefabricated residential blocks), as well as residential blocks with red clay bricks or silicate bricks. These dwelling can be spotted in the form of liner constructions as in the case of the city of Tirana [4].

The large panels, whether horizontal or vertical, are made of concrete, where some of the panels are filled with foam-concrete. The facades of the building are not a continuous element but consist of several small units. The connection of the panels is done using mortar in order to monolithic the structures and the joints between the pannels are considered weak structural points [5]. Most of these buildings have five or six floors and are composed of various modules. The number of the floors depended on the general local plan of the municipality of that time.

These types of buildings do not have a good energy performance because the main material of these buildings is concrete and it is known that concrete has high thermal conductivity and that causes significant heat loss. Many thermal bridges are present in the joint between the concrete panels, which often influence heat loss, and also turn into a problem for moisture infiltration into the building envelope. Because of amortization and lack of maintenance only in the city of Tirana, about 10% of the stock of prefabricated buildings have not had renovation interventions. Due to this situation the problems in these building have been amplified [6]. After their privatization in the early 90s, maintenance and care of the buildings has been the responsibility of the residents. In more than 15 years, the interventions that were made in these buildings were made by the owners, who only intervened in their properties. Only in the last 5 years, the government intervened in some of these types of buildings by thermal insulating them with the external coating system.

2. Evaluation methodology of thermal performance

The evaluation of thermal performance will be done by comparing three different models of the same building. The first model will be the prefabricated building as it was designed in its beginnings, without any kind of thermal intervention. Furthermore, the existing layers of the building envelope, specifically the terrace, ground floor, perimeter walls and windows are considered. In the second model, in addition to the existing construction layers, an external coating system with different layers was added exposing the current state of the building. In the third model, innovative materials will be introduced to increase the thermal performance of the building [7].

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For each model, it is going to be analysed the heat flow from layer to layer and how the thermal insulation characteristics of different materials are affected. The total thermal performance of the building, due to the analized models will be given for each model. The study will not consider the intermadiate floors of the building and the coefficient U of the separation wall is considered to be U=0.4

2.1 Heat flow

Heat transfer means the transfer of kinetic energy. Heat is kinetic energy in transit. Heat transfer is always accompanied by a change in the temperature of an object.

Heat is transferred between two systems or bodies whenever there is a temperature difference between them. The greater the temperature difference between the two bodies, the greater will be the amount of heat that will flow through them. In this migration or transfer, according to the second law of thermodynamics, the natural direction of heat flow between two bodies is from the hotter body to the colder body and never in the opposite direction. The flow of heat from the warmer body to the colder body will continue as long as both objects have the same temperature. So until thermal equilibrium is reached between them. [8]

2.2 Methods of heat transfer

2.2.1 Solar Radiation

Albania belongs to the Mediterranean climate belt and it is caracterised with hot and dry summers and mild winters. The average annual precipitation over the country is about 1485 mm [9]. Albania is considered a country with an upper-average radiation potential, which varies between 1185 and 1700 kWh/(m2·year). The average annual number of sunny days is 240-260 days/year [10]. For Tirana, the average annual sunshine duration is about 2500 h/year and the average annual total solar radiation is 1500 kWh/(m2·year) [11].

Meanwhile, Podgorica is the capital and largest city of Montenegro. Under the Köppen climate classification, Podgorica is transitional between a humid subtropical climate (Cfa) and a hot-summer Mediterranean climate. The n annual rainfall is 1956 mm [12]. In Podgorica, the yearly sum of sunshine is estimated to be around 3065.99 hours. On average, this equates to a monthly figure of approximately 100.6 hours for each month [12].

The research have shown that there are small differences in terms of solar radiation between Tirana and Podgorica.

2.2.2 Temperatures

Calculations for heat transmission will be made with the MEEC application, which is a program used in Montenegro [13], [14]. Since Podgorica is the closest city to Albania, the calculations will be made with the mean temperatures of that city. According to a technical report made by Kamez Municipality [15], this area is included in the central plain Mediterranean climatic zone. The average annual temperature ranges from 15-16˚C. The maximum temperature was recorded on 13.07.1973 with 43˚C, while the minimum temperature was recorded on 15.01.1968 with - 14.4˚C. The amplitude of the changes between day and night is significant and ranges from 6 to 12-14˚C. For the city of Podgorica, the temperatures to be calculated are recorded directly in the program. In Podgorica, the average January temperature is 5.0° C, July 25.9° C, while the annual temperature is 15.3° C.

Meanwhile according to RETscreen expert (a Canadian application) the anual temperature in Tirana is also 15.3° and the avarage January temperature is 7° C, which means that the two cities have little differences in terms of climate parametres [8].

2.2.3 Thermal balance

Gain= Losses

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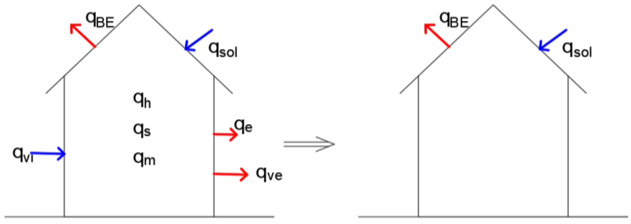
The term "gain= Losses" refers to a situation where the heat gain in a system is equal to the heat losses. This means that the amount of heat entering the system is equal to the amount of heat leaving the system, and there is no net change in the temperature of the system.

$$q_s + q_m + q_{sol} + q_h + q_{vi} = q_{BE} + q_e + q_{ve} \quad (1)$$

Where:

q_s –Sensible gain, q_m -mechanical gain, q_{sol}-solar gain, q_h- supplementary heating, q_{vi} –ventilation inside, q_{BE} heat transfer building envelope, q_e -losses through evaporation, q_{ve} -ventilation outside

Using MEEC application the study will be focused just in building thermal performance and the simplifications and the calculation scheme will be as below:



a) b)

Figure 1. a) The real heat transfer proces b) the simplification of heat transfer; source: authors

So the expression (1) becomes:

$$q_{sol} = q_{BE} \quad (2)$$

Benefits as a result of solar radiation. SHGC (solar heat gain coefficient) is calculated in the window.

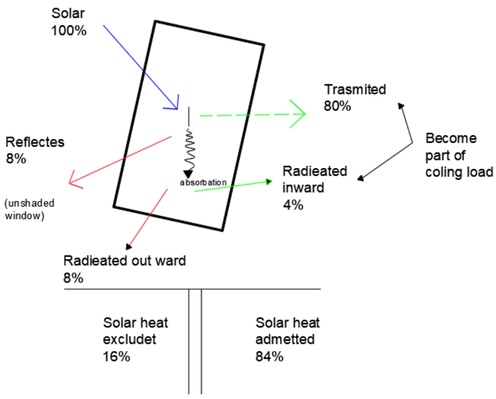


Figure 2. Solar radiation in window, source: authors

The calculation of heat transfer through a building element is

$$q_i = (G_i) * (SHGC) \quad (3)$$

Where

q_i Is the heat transfer through the element (in units of energy per unit time), (G_i) Incident irradiation, SHGC portion translated to heat gain

Fourier's law for thermal conduction in masonry

Fourier's law is used to describe the flow of heat in a solid material, such as masonry. It states that the rate of heat transfer through a material is proportional to the temperature gradient in the material and

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the cross-sectional area perpendicular to the direction of heat flow, and is inversely proportional to the material's thermal conductivity. In other words, the equation for Fourier's law of heat conduction can be written as:

$$Q_{wall} = -kA\frac{\dot{T}_2 - T_1}{L} = -\frac{T_2 - T_1}{R_t} \qquad (4)$$

Where:

Q_{wall} is the rate of heat transfer (W), k is the thermal conductivity of the material (W/m.K), A is the cross-sectional area perpendicular to the direction of heat flow (m^2), L is the plane thickness (m), R_t Is thermal resistance , $T_2 - T_1$ Constant temperatures

In nature, heat transfer occurs in the following ways: by convection; by conduction; by radiation.

Heat transfer by conduction

Conduction is the process of heat transfer within a solid body (from one part to another) or between two bodies that are in direct contact with each other. In heat transfer by conduction, heat is transferred from one molecule to another neighboring molecule, which is in contact with it, through vibration, but without changing their position [16].

Different materials have different thermal conductivities (or conductivity) of energy. They can be compared with each other through the values of "U" as well as through the values of "R".

The value of "U" itself represents the coefficient of thermal conductance or transmittance and is also known differently as the heat transfer coefficient. The "U" value of a body indicates the heat transferred through one square meter of its surface, per unit of time, when the temperature difference between the external and internal environment is 1 °K (or 1ºC). The unit of measurement of the "U" value is: (W/m²K or W/m²°C). Usually solid bodies are better conductors than liquids, while liquids are better conductors than gases. The value of "U" is determined through the following relation:

$$U = \frac{1}{R} \qquad (5)$$

In those cases when a component of the building is composed of several layers of different materials, then the overall thermal transmittance value (or heat transmission coefficient) "UT" will be defined as the sum of the thermal transmittance of each material:

$$U_T = U_1 + U_2 + \cdots \ldots + U_N \qquad (6)$$

The value of "R" represents the thermal resistance of different materials, which means resistance to heat loss. The higher the "R" value, the more thermally insulating a material will be, and the higher the energy saving will be. In those cases when a building component is composed of several layers of different materials, then the general value of thermal resistance "RT" will be determined as the sum of the thermal resistances of any material:

$$R_T = R_1 + R_2 + \cdots \ldots + R_N \qquad (7)$$

2.3. Thermal camera

On 13.12.2022 at 13:30 some measurements were made with thermal cameras in the city of Kamza. During the measurements the air temperature was 13°C and the humidity was 43%. This examination was carried out according to EN 13187 using a thermal imager TESTO 882. The results are shown in images with different colors that represent the temperature fluctuations. The lower temperatures are presented with black and dark blue colors. As the surface temperatures increases, the color changes from red, purple to yellow.

In the Figure 3 below are represented the results for one of the facade of the existing building.

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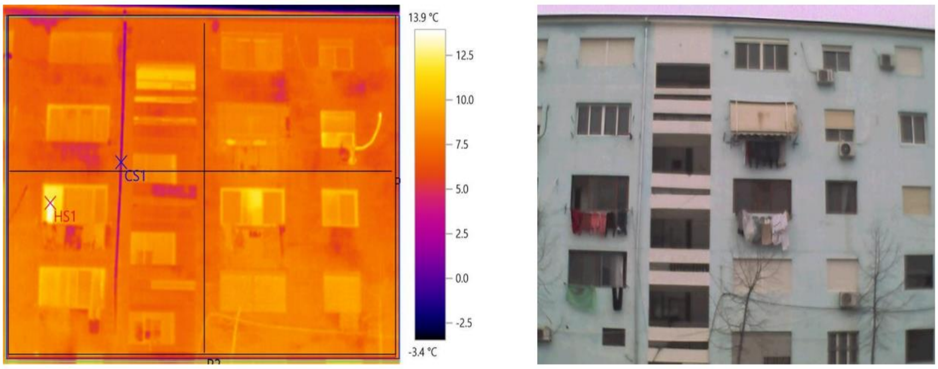
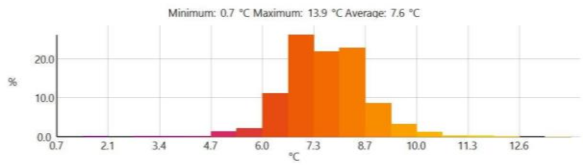
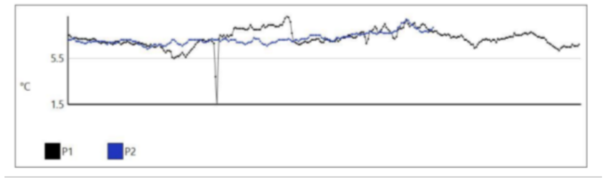


a)

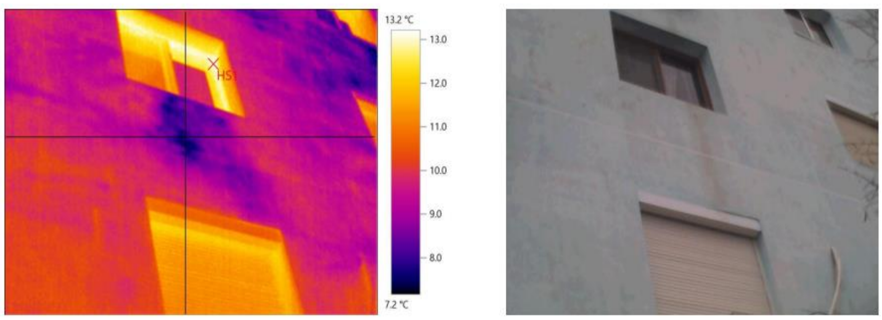




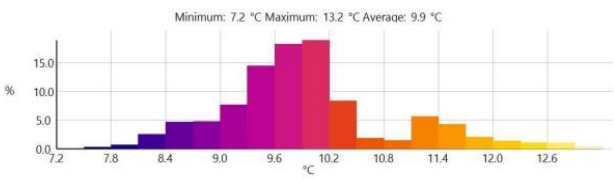
b) c)

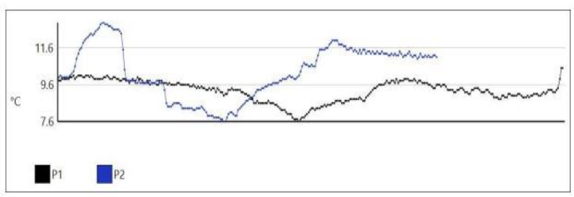
Figure 3. a) The facade temperatures, b) Histogram, c) Profile line; source: authors

In the facade as seen in Figure 3, two temperature profile lines are taken into consideration, one is horizontal and the other one is vertical. The graph presented above shows how the temperatures change along of the profile lines. The histogram shows the information about the maximum and minimum temperature as well as the average temperature on this facade. The point with the minimum temperature is marked with CS1 and the temperature is 0.7°C, which is called cold spot. According to the photo it is observed that this point is located on a metal exhaust pipe. Point HS1 is the point with the highest temperature of 13.9°C. Also, many purple spots are observed indicating the presence of moisture, which is accompanied by lower temperatures compared to the rest of the facade. According to figure 3, c, it is observed that in both the horizontal line P1 and vertical line P2 directions the temperature fluctuation is almost horizontal but the P1 at a certain point shows a drop of temperature because of the coldest point located in the thermal photo.



a)





b) c)

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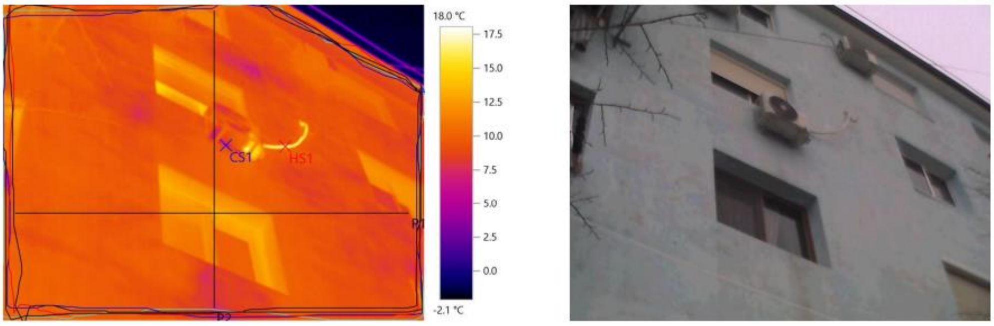
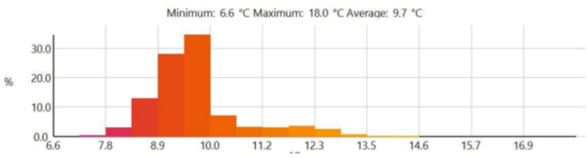
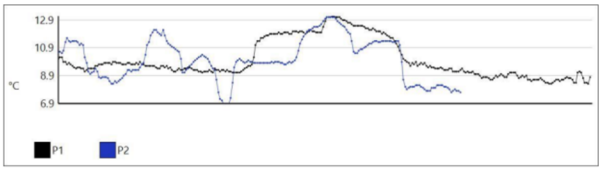
Figure 4. a) The window section, b) Histogram, c) Profile line

In the fragment of the facade as seen in figure 4, it is clearly observed the heat flow from the inside to the outside due to the poor connection of the window to the wall, where the hot point is found precisely in this connection. A little further down, near the window the hot spot can be observed, which is located in a plastic grille, that had a higher temperature than the facade. Plastic is a material with near zero water absorption in relation to the other part of the facade, which is saturated with water due to rainfall. In this fragment, the presence of moisture can be clearly distinguished, especially in the lower part of the window in figure 4. a, as a result of the lack of window drip detail. Furthermore, the presence of moisture is evident, and as a consequence lower temperaturas are observed. In the profile line fig. 4.c, it can be seen that both the horizontal and vertical directions have different temperature fluctuations.



a)





b) c)

Figure 5. a) Air condition, b) Histogram, c) Profile line

Figure 5, shows two air conditioners, but with the help of the thermal camera, it is easy to observe that one of them is operating fig.5.a, and the other is not. The air conditioner pipe has a lighter yellow color, which indicates higher temperatures range. The hot spot appears precisely in the tube and the cold spot appears in the lower part of the air conditioner. In the profile line fig.5.c, it can be seen that both the horizontal and vertical directions have temperature fluctuations.

3. Case Study

The building under study is located in Manhatan Street in the city of Kamze. Kamza is a city northwest of the city of Tirana.

a) b)

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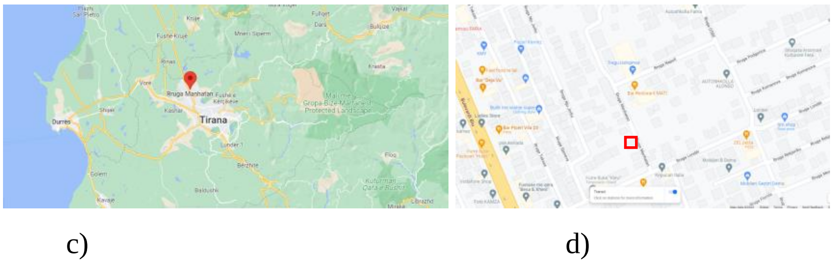

Figure 6. a) The building after the intervention; source authors b) the building without any intervention, source: authors c) location of te Manhatan Street, source: Google Earth d) A closer aerial look buildings, source: Google Earth

Only one block of section 2.1 was considered. The drawings are taken from AQTN [17].

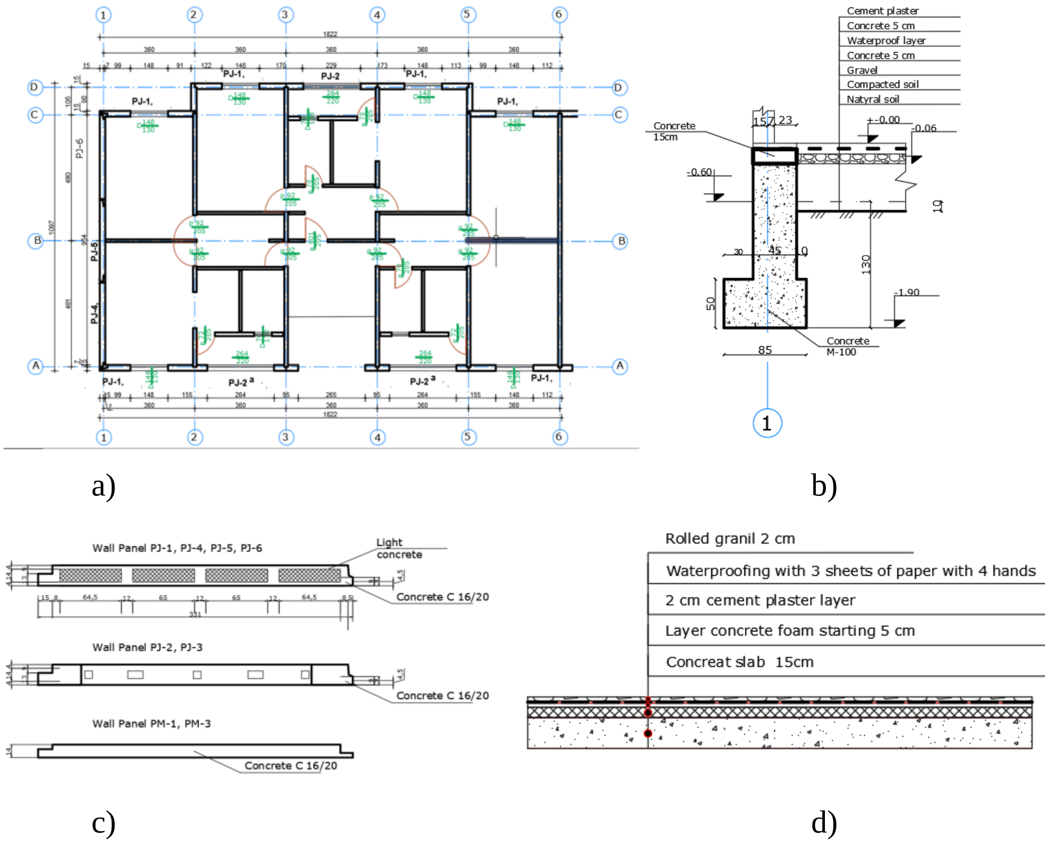

Figure 7. a) The plan of the building, b) foundation section c) wall cross sections d) slab section

Materials used for different elements, the characteristics of the materials are taken from technical design code [17] and the methodical guide for calculating the seismicity of building constructions [18].

For the vertical panels used as part of building envelope and partition walls. Large precast concrete panels are made from a mixture of cement, water, and aggregates, with the mix typically modified to improve the insulation properties of the panels, they can range in size from several meters in length, width, and height, with a typical thickness of 15 to 40 centimeters. Figure 7, c show the section Wall used in the key study and has the following features are used:

- Concrete class C16/20 unit weight $\gamma = 2400kg/cm^2$.
- Foam concrete unit weight $\gamma = 500kg/cm^{2.}$

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For the basements, different layers are used as can be seen in Fig. 7. d, and each layer has the following characteristics

- Concrete C16/20 with an approximate weight $\gamma = 2400 kg/cm^2$
- The foam concrete unit weight $\gamma = 500 kg/cm^2$.
- Cement plaster with a unit weight $\gamma = 2000 kg/cm^2$
- Waterproofing with a unit weight $\gamma = 1200 kg/cm^2$

For the basements, different layers are used as can be seen in fig.7.b, and each layer has the following characteristics

- Concrete C16/20 with an approximate weight $\gamma = 2400 kg/cm^2$
- The foam concrete unit weight $\gamma = 500 kg/cm^2$.
- Cement plaster with a unit weight $\gamma = 2000 kg/cm^2$
- Waterproofing with a unit weight $\gamma = 1200 kg/cm^2$
- Gravel $\gamma = 1200 kg/cm^2$

The second calculated model is the building in the existing state as it is now. As mentioned above, in recent years, an intervention has been made in these buildings. A thermal insulation layer has been added to the external walls. The thermal insulation is made by an external coating system with layers, a 7 cm layer of polystyrene is applied and the other layer is adhesive in order to connect polystyrene with the wall. There are also implemented other layers such as plastic nets, basecoat adhesive primer and finishing coat.

The third model is the proposed interventions applied in the external walls, terrace, foundation and in the windows. The proposed windows have U=0.68 W/(m^{2}K), the terrace U=0.27 W/(m^{2}K), and the basement U=0.78 W/(m^{2}K). The ground contact of the building will not be subject to further improvements, becuase the intervantion is rather difficult. The large prefabricated panels according to the calculation will have a U=0.26 W/(m^{2}K) with light concrete and U=0.68 W/(m^{2}K).

For calculation proposals the surfaces of the building envelope are calculated in Table 1 and 2.

Table 1-Wall and Window surface calculations

Orientation	Panel Type	Wall Area (m^2)	Window Area (1,48*1,3) (m^2)	Window Area (2,64*2,2) (m^2)
North	PJ-4, PJ-5, PJ-6, PJ-B	155,952	0	0
South	PM-1, PM-3, PJ-B	140,495	0	0
West	PJ-2	51,264	0	29,04
	PJ-1,	205,056	38,48	0
East	PJ-1,	102,528	19,24	0
	PJ-2, PJ-3	121,848	0	58,08

Table 2-Slab surface

	Quantity	Slab Area (m2)	Openings	Net surface (m^2)
Slab panel type 1 (S 1)	14	8,5383	0	119,5362
Slab panel type 2 (S-2)	3	13,3534		40,0602
Slab panel type 3 (S-3)	3	7,4464	0	22,3392
Total				181,9356

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4. Results

MEEC application is used in order to observe the building thermal performace for the specific models.

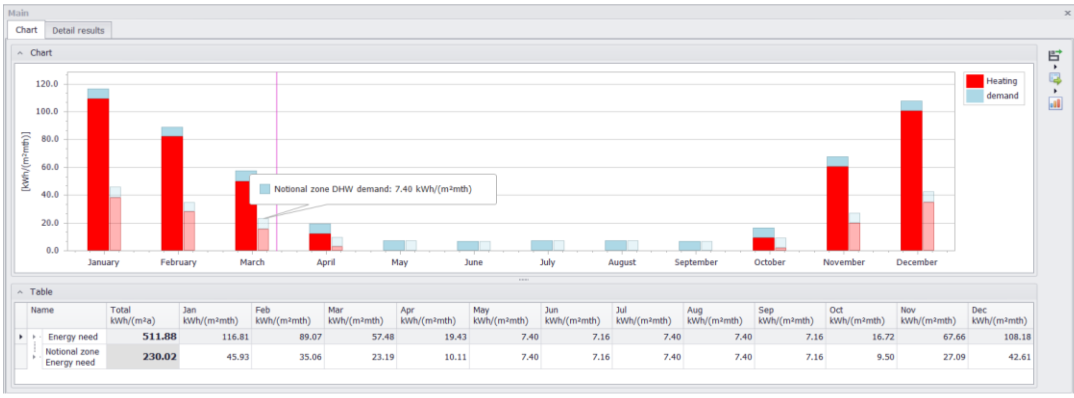

Figure 8. The results obtained for the model without thermal intervention

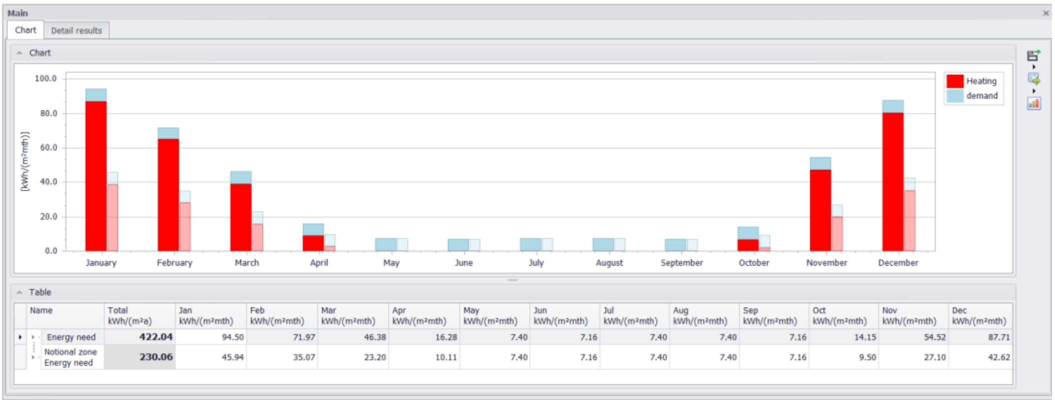

Figure 9. The results obtained for the model according to the existing intervention

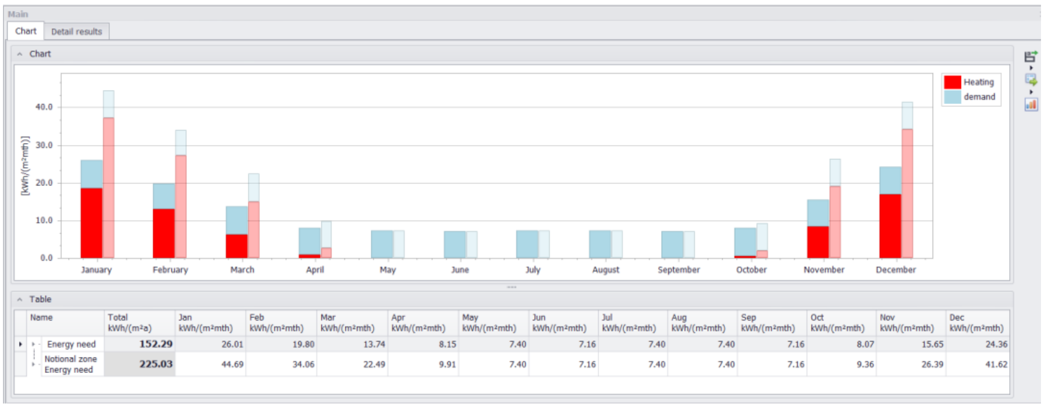

Figure 10. The results obtained for the model with proposed intervention

According to the obtained results extracted from the application, it can be observed how the required energy changes in the three cases. For the first model, in January, the required energy is 511.88 kwh/(m^{2}a), while in the second model 422.04 kwh/(m^{2}a) is required, which means a reduction of 17.55% in the energy required. For the third model, the required energy is 150.54 kwh/(m^{2}a), which means a reduction of energy need of 70.59% in relation to the first model and 64.33% to the second model.

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The introduction of foam concrete in the wall can decrease the U-value by 58.5%, reducing it from U = 3.57 W/(m2K) for the PJ-2 panel wich has foam concrete with a west orientation to U = 1.48 W/(m2K) for the PJ-1 panel which is the whole panel concrete C16/20, also facing the west.

5. Conclusions

It is observed in the existing situation that water absorption is relatively high, which negatively affects its thermal performance. The presence of water in the facade will increase the coefficient of thermal performance (U value) as a result of water absorption above the allowed rates.
Windows are one of the buildng elements with the highest heat flow, so it is necessary to intervene in these elements to significantly improve the thermal performance of buildings. The existing thermal performance of them is very poor.
In the case of old prefabricated buildings, it is recommended that before starting the application of the thermal insulation system, the foundation, exterior walls, terrace and windows must be requalified in terms of thermal performance. Insulation of all joints between prefabricated panels, surface treatment with concrete asar - contact concrete weberprim is needed.
The intervention only in the external walls brings a very small difference in the heat flow from the inside to the outside of the building so the terrace still needs thermal insulation. It is observed that the reduction of the U-value of the window can be of higher bennefits in terms of building thermal performance, moreover, their immediate improvement is strongly recommended.

References

[1] European Commission (2018), ‘Assessment of the application of the EGTC regulation’, Final report – 20.04.2018, written by Spatial Foresight, Project number 2017CE160AT116.

[2] Marku, A., (2022), SUSTAINABILITY - Low-cost strateg Low-cost strategies for renovation of Residential Building Stock of the 70s-80s in Albania. (Accessed December 1, 2022).
(https://issuu.com/polisuniversity/docs/phd_thesis_aguljeln_marku)

[3] Novikova, A., Z. Szalay, G. Simaku, T. Thimjo, B. Salamon, T. Plaku, and T. Csoknyai 2015. *The typology of theresidential building stock in Albania and the modelling of its low-carbon transformation*. Project SLED, RegionalEnvironmental Center for Central and Eastern Europe, Vienna. (Accessed December 7, 2022).

[4] K. Xhexhi (2021) “The impact of building materials in inhabitance lifestyle, case of Kruja, Albania” ISBN 9781639028627

[5] Guri, M., Brzev, S., Lluka, D., (2021), *Performance of Prefabricated Large PanelReinforced Concrete Buildings in the November2019 Albania Earthquake. Taylor&Fancis,* (3-6) *https://www.researchgate.net/deref/https%3A%2F%2Fdoi.org%2F10.1080%2F13632469.2021.1887010*

[6] GJERGJI, I., (2016). Përmirësimi i performancës energjetike në banesat me panele të parapërgatitura në Tiranë. [Improvement of energy performance in houses with prefabricated panels in Tirana].

[7] B. C. (17). Windows and glazed area technologies and materials in Europe. Building Envelope Technologies and Policies Workshop. Neuilly-sur-Seine.

[8] Xhexhi, K., (2023) Ecovillages and Ecocities. Bioclimatic applications from Tirana, Albania. ISBN 978-3-031-20958-1

[9] Albania’s Second National Communication to the Conference of Parties under the United Nations Framework Convention on Climate Change. Tirana, 2009. Available at: http://unfccc.int/resource/docs/natc/albnc2.pdf
[10] Renewable energies in Albania-Solar energy, Table 1. Accessed on December 2022. Available at: http://www.akbn.gov.al/images/pdf/energji-terinovueshme/Energjia_Diellore.pdf.

[11] Tirana: Albania, Geographical names. Accessed on December 2022. Available at: http://www.geographic.org/geographic_names/name.ph p?uni=-168608&fid=283

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Zagreb, Croatia - March 22 to 24, 2023

DOI: https://doi.org/10.5592/CO/2CroCEE.2023.63

[12] Podgorica climater, Accessed on December 2022. Available at: https://en.climate-data.org/europe/montenegro/podgorica/podgorica-1324/

[13]Budde, E., Erhorn, H., Koutsomarkos, K., Wössner, S., 2020, Technical Manual MEEC—Montenegrin Energy Efficiency Certification, Technical manual, Montenegro.

[14]Budde, E., Erhorn, H., Koutsomarkos, K., Wössner, S., 2020, Technical Manual MEEC—Montenegrin Energy Efficiency Certification, User manual, Montenegro.

[15] Bashkia Kamez. (n.d). Raport teknik. Market project. Retrieved December 13, 2022, from https://openprocurement.al/tenders/relacion/26890.pdf

[16]John H. Lienhard IV, Professor John H. Lienhard V, 2001, A Heat Transfer Textbook, Third Edition, Cambridge, Massachusetts, U.S.A. http://web.mit.edu/lienhard/www/ahtt.html

[17]AQTN, ARKIVI QËNDROR TEKNIK I NDËRTIMIT.[CENTRAL TECHNICAL BUILDING ARCHIVE].

[18] KTP-N.2-89. 1989. Kusht teknik projektimi per ndertimet antisizmike KTP-N.2-89 [Technical design code for earth-quake-resistant construction KTP-N.2-89]. Tirana, Albania: Akademia e Shkencave.

[19] AKADEMIA E SHKENCAVE & MINISTRIA E NDERTIMIT. (1990). Udhezues Metodik per llogaritjen ne sizmicitet te konstruksioneve ndërtimore.[Methodical guide for calculating the seismicity of building constructions].Tirane. 1990.