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ENERGY DEMANDS OF THE EXISTING COLLECTIVE BUILDINGS WITH BEARING STRUCTURE OF LARGE PRECAST CONCRETE PANELS FROM TIMISOARA

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ABSTRACT:

One of the targets of EU Directives on the energy performance of buildings is to reduce the energy consumption of the existing buildings by finding efficient solutions for thermal rehabilitation. In order to find the adequate solutions, the first step is to establish the current state of the buildings and to determine their actual energy consumption. The current paper aims to present the energy demands of the existing buildings with bearing structure of large precast concrete panels in the city of Timisoara. Timisoara is one of the most important cities in the west side of Romania, being on the third place in terms of size and economic development. The Census of Population and Housing of 2011 states that Timisoara has about 127841 private dwellings and 60 percent of them are collective buildings. Energy demand values of the existing buildings with bearing structure of large precast concrete panels in Timisoara, in their current condition, are higher than the accepted values provided in the Romanian normative, C107. The difference between these two values can reach up to 300 percent.

1. INTRODUCTION

1.1. General Instructions

According to The Census of Population and Housing of 2011, in Romania, from the total of 20121641 inhabitants, 54 percent live in urban areas. Romania has a surface of 237500 km^2 and the urban areas represent approximately 10 percent of this surface, meaning that the population density is 153 peoples/ km^2 on urban areas as far as population density in Romania is 92 inhabitants/ km^2 (The Census, 2011).

In urban areas, more than 60 percent of the inhabitants live in collective buildings. Most of the collective buildings have bearing structure of large precast concrete panels and were built between 1962 and 1992. It is estimated that Romania has approximately 57000 buildings with bearing structure of large precast concrete panels (Pescari, 2015).

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The current paper aims to present the energy demands of the existing buildings with bearing structure of large precast concrete panels in the city of Timisoara.
Timisoara is one of the most important cities in the west side of Romania, being on the third place in terms of size and economy.

The Census of Population and Housing of 2011 states that the city of Timisoara has about 127841 private dwellings. Most of these dwellings are residential houses and apartments in different types of collective buildings. In Timisoara, the collective buildings represent about 60 percent from the total number of dwellings.

Even though Timisoara is considered a modern city, most of the buildings dates since 1962. Then, the main goal was to build as faster as possible and to provide as many dwellings as possible. In order to satisfy the needs of that time period, the easiest way was to build using precast elements. Therefore, all the collective buildings built during 1965-1992 are buildings with bearing structure of large precast concrete panels.

2. BUILDINGS WITH BEARING STRUCTURE OF LARGE PRECAST CONCRETE PANELS IN TIMISOARA

According to the Development Site Plan of the city between 1972 and 1985, in Timisoara were built approximately 4200 buildings of five storeys with precast panels. The number of buildings was established using the Development Site Plans, and was verified by counting the buildings from each street. It was checked only 60 percent of total number of streets in Timisoara, therefore 3640 is an estimated number, and the error might be somewhere between 50-100 buildings. The buildings were built using standard projects developed by IPCT and used in all of the Romanian cities. After a while, these projects were adapted for different conditions required by each city.

For Timisoara, the standard project IPCT was modified and adapted by IPROTIM.
The Development Site Plan from which was established the stock of buildings with bearing structure of large precast concrete panels in Timisoara, was design by IPROTIM.

According to the work plan, in Timisoara were adopted three standard projects: T744-IPCT, T770-IPCT and T1340-IPCT.

The first standard project was T744-IPCT, which was used between 1962 and 1977. T744-IPCT took into account only vertical loads and for this reason the precast panels were relatively too large and the thickness of the structural layer of the panel was too low. Also the reinforcement area was too low (Botici A, 2012), (Botici A, 2014).

The second standard project, T770-IPCT emerged as a solution to the 1977 earthquake. Compared to the T744-IPCT project, the thickness of the structural layer of the panels was higher. It was the first time when the panels and buildings in general were designed taking into account the seismic hazard.

The third standard project, T1340-IPCT, is considered to be a combination between T744-IPCT and T770-IPCT. The configuration of the panels was similar to T744-IPCT panels but the thickness of the panels was higher. This third standard project was the last attempt of buildings with bearing structure of large precast concrete panels in Timisoara.
Also, in addition to these three standard project adopted by IPROTIM and used in Timisoara, there were several other projects, called special standard projects. The most used special project was the T863-IPCT project. The only difference between this one and the three standard projects mentioned above is the typology of the section. T863-IPCT is known to have extremely large rooms compared to other special types of projects. Were used large panels, most of them with a length of 4.40 m while for the other three project the largest panels had only a length of 4.00 m, except for the project T770-IPCT design in 1977, for which the interior panels had a length of 5.10 m (Botici A, 2014).

All the standard projects are divided in typology sections depending on the specific needs of each zone. Therefore, one standard project has ten or more different horizontal and vertical sections. These sections are called “Pb section” or Db section”.

As stated above, in Timisoara were three types of prevalent standard projects, but depending on the section typology, in Timisoara are more than 50 different sections, 15-20 section for each of the three standard projects.

3. ENERGY BALANCE PARAMETERS OF THE BUILDINGS WITH BEARING STRUCTURE OF LARGE PRECAST CONCRETE PANELS

In order to evaluate the energy balance, the first step is to determine the geometrical parameters: the envelope dimensions, the heated floor area and the thermal parameters of the envelope. The thermal parameters refer to the thermal transfer resistance/heat transfer coefficient, building equipment and climate data (Mc001, 2006).

The energy balance was made using the Romanian normative. According to this, the area of the envelope elements was calculated considering the interior dimension of the elements. Therefore, the heated floor area is the sum of all floors areas bounded by exterior walls. For the vertical envelope elements was took into account the geographical orientation for each exterior wall, exterior doors and windows. Also, in order to perform the energy balance for different typology of buildings with bearing structure of large precast concrete panels, were used two hypothesis: first is that the staircase is heated for all the buildings and the second refers to the geographical orientation, so the main façade is facing west, secondary façade is facing east and the lateral façades are facing north and south.

The evaluation was made using the exterior climate data in Timisoara area. It was considered an exterior winter temperature of -15°C and a heating period of 197 days/year (Tudor, 2010) (Moga, 2009).

Was analysed the first typology for each standard project, thus:

- For the standard project T744-IPCT, it was chosen the typology Db1. This one was the most used for T744, and even though it was designed in 1962, has undergone several changes over time;

- For the standard project T770-IPCT, it was chosen the typology Pb4. The first typology for T770 was Pb1, but this typology was not used in Timisoara. The Pb2 typology was a combination between Pb1 and the standard project T744-IPCT. Only a few buildings were built using the Pb2 typology. The most used typology for T770-IPCT project in Timisoara was the Pb4 typology.

- For T1340-IPCT was chosen the standard typology. This type of standard project was a combination between T744-IPCT and T770-IPCT and it was used to create a connection building to link two buildings together on the street corner.

3.1. The standard project T744-IPCT

The buildings made using this standard project are the most common prefabricated buildings in Timisoara. The typology Db1 is the most representative typology for T744-IPCT, being considerate the skeleton for the T744-IPCT project (Catalogue type, 1970).

This type of precast building is a five storey structure with an unheated storage basement. The roof is an uncirculated terrace roof. The building has 4 apartments on each storey, 3 apartments with 2 rooms and 1 apartment with 3 rooms, except for the ground floor, which has 4 apartments with 2 rooms, as it can be seen in figure 1.

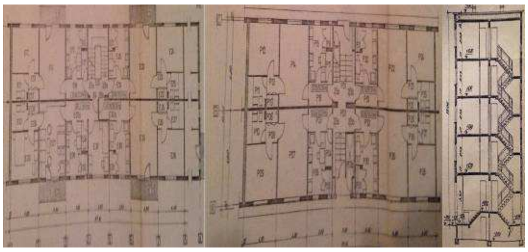

Figure 1. The standard project T774-IPCT Db1; horizontal section of the current floor on the left, horizontal section of the ground floor in the middle and vertical section on the right

3.1.1. Geometrical parameters: The analysed building has 27.42 m length, 10.00 m width and height of 15.06 m.

According to the Romanian methodology and using the hypothesis that the staircase is heated, the heated floor area is 1271.42 m^2 (254.28 m^2/floor) and the heated volume is 3436.98 m^3. The envelope elements are: exterior walls, windows, exterior doors, roof terrace and the floor above the unheated basement.

The envelope elements have the following dimensions:

- Exterior walls: west façade 251.73 m^2; east façade 274.23 m^2; south façade 62. 48 m^2 and north façade 62.48 m^2;
- Windows and exterior doors: west façade 110.34 m^2; east façade 87.84 m^2; south façade 20.50 m^2 and north façade 20.50 m^2;
- Roof terrace 254.28 m^2;
- Floor above the unheated basement 254.28 m^2.

3.1.2. Thermal parameters: The thermal parameters refer to the thermal transfer resistance/heat transfer coefficient for each element of the envelope and to the climate data. The exterior walls are made from precast panels composed by three different layers with different functions.

The interior layer is the structural layer made of reinforced concrete with a thickness of 110 mm. The second layer, also known as the middle layer of the panel is the thermal insulation layer with a thickness of 100 mm made of autoclaved cellular concrete. The last layer with the protection role made of concrete has a thickness of 60 mm.

The roof is also from precast panels and is made of five or more layers. The most important layers from the thermal resistance point of view are the reinforced concrete layer with 130 mm thickness, the autoclaved cellular concrete layer with 100 mm thickness and the protection concrete layer with 40 mm thickness. The others layers from the roof are the waterproofing layer with 6 mm thickness and the support layer made from cement plaster. The floor above the unheated basement is composed of two layers, 130 mm reinforced concrete layer and 20 mm parquet layer and it was not provided with thermal insulation layer.

All the windows of the building were changed to double glazed windows. The thermal resistance and heat transfer coefficient for each element of the envelope are presented in table 1.

Element	R-value [m^{2}K /W]	U-value [W/m^{2}K]
Exterior walls	0.450	2.222
Terrace roof	0.620	1.612
Floor above basement	0.297	3.367
Windows and exterior doors	0.380	2.631

Table 1. Thermal parameters for T744-IPCT Db1

3.2. The standard project T770-IPCT

This type of project was designed and adopted after the 1977 earthquake. The most representative typology for this standard project was Pb4. Like T744-IPCT Db1, this type of precast building is also a five storey structure with an unheated technical basement used for storage. The roof is an uncirculated terrace roof. The building has 4 apartments on each storey, 4 apartments with 3 rooms, except the ground floor, which has 3 apartments, 2 apartments with 3 rooms and 1 apartment with 4 rooms, as it can be seen in figure 2 (Catalogue type, 1978).

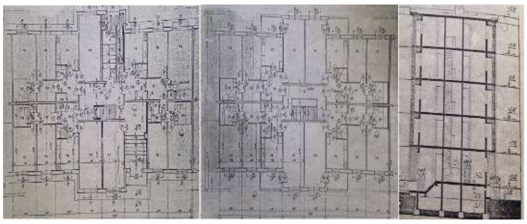

Figure 2. The standard project T770-IPCT Pb4; horizontal section of the ground floor on the left, horizontal section of the current floor in the middle and vertical section on the right

3.2.1. Geometrical parameters: This type of precast building has 27.87 m length, 14.20 m width and height of 15.00 m. According to the Romanian normative and using the hypothesis that the staircase is heated, the heated floor area is 1685.80 m^2 (331 m^2 for ground floor and 338.70 m^2/ upper floor) and the heated volume is 4435.40 m^3. The envelope elements are: exterior walls, windows, exterior doors, roof terrace, floor over air (is the floor above the secondary building entrance) and the floor above the unheated basement.

The envelope elements have the following dimensions:

- Exterior walls: west façade 303.68 m^2; east façade 339.20 m^2; south façade 137.18 m^2 and north façade 137.18 m^2;
- Windows and exterior doors: west façade 129.48 m^2; east façade 113.01 m^2; south façade 36.72 m^2 and north façade 36.72 m^2;
- Roof terrace 338.70 m^2;
- Floor over air 7,70 m^2;
- Floor above the unheated basement 331.00 m^2.

3.2.2. Thermal parameters: Like T744-IPCT, the exterior walls are from precast panels. The interior layer is the structural layer, made of reinforced concrete with a thickness of 125 mm. The second layer located in the middle of the panel is the thermal insulation layer made of 85 mm of EPS. The exterior layer made of concrete with a thickness of 60 mm has the protection role. The stratification presented was the originally planned in the project and it was used only for a few buildings. Afterwards, the stratification was changed: the thermal insulation layer was changed to an autoclaved cellular concrete layer or to a combination between EPS and mineral wool. For the energy evaluation, was considered almost the same thermal resistance for all used panels. The roof, the floor above the unheated basement and windows are the same as for the project T744-IPCT Db1. The floor over air has the same configuration like the floor above the unheated basement. Therefore, the thermal transfer resistance and heat transfer coefficient for each element of the envelope are presented in table 2.

Element	R-value [m^{2}K /W]	U-value [W/m^{2}K]
Exterior walls	0.979	1.021
Terrace roof	0.620	1.612
Floor above basement	0.297	3.367
Floor over air	0.297	3.367
Windows and exterior doors	0.380	2.631

Table 2. Thermal parameters for T770-IPCT Pb4

3.3. The standard project 1340-IPCT

This type of project is not common in Timisoara. The prefabricated building made using this typology are known as the corner buildings because the project is a combination between T744 and T770 used to enclose a corner. The interior configuration (the apartments and the staircase) is the same with T770 configuration, the dimensions of the panels are the same with T744 panels' dimensions and the layers of the panels are almost similar with the layers of the T770 panels.

Like the other two types of project, T1340-IPCT is also a five storey structure with an unheated technical basement used for storage. The roof is an uncirculated terrace roof (Catalogue type, 1978).

Unlike the other two types of buildings presented above, this one does not have a regular configuration.

The building has 4 apartments on each storey, 4 apartments with 2 rooms, except the ground floor, which has only 3 apartments with 2 rooms, used as an office room and a dryer room, as it can be seen in figure 3.

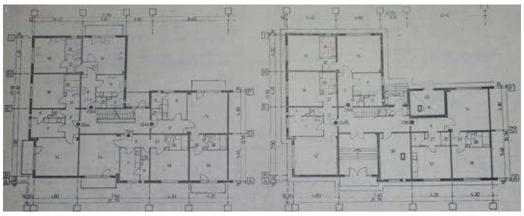

Figure 3. The standard project T1340-IPCT; horizontal section of the current floor on the left, horizontal section of the ground floor on the right

3.3.1. Geometrical parameters: This type of precast building does not have a regular configuration, therefore the dimensions of the building are: 21.79 m length, 10.58 m width on one side and 17.18 m length, 10.60 m width on the other side. This dimension are presented in figure 4. The height of the building is 15.00 m. According to the Romanian normative and using the hypothesis that the staircase is heated, the heated floor area is 1275 m^2 (255 m^2/ floor) and the heated volume is 3279.30 m^3. The envelope elements for this type of building are: exterior walls, windows, exterior doors, roof terrace, floor over air (is the floor above the secondary building entrance) and the floor above the unheated basement.

The envelope elements have the following dimensions:

- Exterior walls: west façade 225.08 m^2; east façade 224.54 m^2; south façade 135.25 m^2 and north façade 174.25 m^2;
- Windows and exterior doors: west façade 80.34 m^2; east façade 80.88 m^2 and south façade 39.00 m^2;
- Roof terrace 255.00 m^2;
- Floor over air 7.70 m^2;
- Floor above the unheated basement 255.00 m^2.

3.3.2. Thermal parameters: The characteristics of the envelope elements of this typology are the same with the characteristic of the T770-IPCT Pb4 envelope elements, except for the thermal insulating layer from the vertical panels (walls), where, instead of the EPS layer of 85 mm, it was used an 80 mm layer of mineral wool.

The mineral wool layer is affected by condensation and by aging. The thermal transfer resistance and heat transfer coefficient for each element of the envelope are presented in table 3.

Element	R-value [m^{2}K /W]	U-value [W/m^{2}K]
Exterior walls	1.140	0.877
Terrace roof	0.620	1.612
Floor above basement	0.297	3.367
Floor over air	0.297	3.367
Windows and exterior doors	0.380	2.631

Table 3. Thermal parameters for 1340-IPCT

4. ENERGY DEMANDS

4.1. Energy demands of buildings with bearing structure of large precast concrete panels

For the energy consumption evaluation of existing buildings was used the Romanian software tool Doset-PEC designed and used for buildings energy evaluation. It was developed by DOSETIPMEX from Timisoara, in accordance with Romanian normative requirements. To evaluate the energy demands, the software mentioned above needs the following information: the heated floor area, the heated volume, the dimension of the envelope elements; the thermal resistance of each element of the envelope, the type of the windows, the number of inhabitants, the heating system, the climate data and the exterior temperature (Prada, 2009).

Therefore:

-The heated floor area, the heated volume, the dimension of the envelope elements, the thermal resistance of each element of the envelope and the type of the windows were described in chapter 3 for each type of typology;

-The number of inhabitants is used to evaluate the energy for domestic hot water. Were considered 2 persons for one apartment which is equivalent with an occupancy index of 0.077 for Timisoara according to Romanian normative;

- It was used the climate data for Timisoara, which is in climate zone 2. The obtained results are presented in table 4.

Project	T744-IPCT Db1	T770-IPCT Pb4	1340-IPCT
Heating [kWh/m^{2}year]	281.90	240.80	212.90
Domestic hot water [kWh/m^{2}year]	73.40	70.10	74.60
Lighting [kWh/m^{2}year]	11.00	11.00	16.10
Total energy consumption [kWh/m^{2}year]	366.30	321.90	303.60

Table 4. Annual energy consumption for different typologies of buildings with bearing structure of large precast concrete panels in Timisoara

As it can be seen in table 4, the greatest differences between the three types of projects are on energy consumption for heating. Such differences are due to the different thermal resistances of the elements of the envelope.

As it was described above, the terrace roof, the floor above the technical basement, the windows and the exterior doors have the same thermal resistance. The only differences are at the composition of the exterior walls. The low thermal resistance of the exterior wall for the building built in compliance with T744-

IPCT project, Db1, has a significant impact on the energy consumption for heating.

According to table 4, the energy consumption for heating accounts for about 75 percent from the total energy consumption. The energy demand for heating are 281.90 kWh/m^{2}year for the standard project T744, Db1, 240.80 kWh/m^{2}year for the standard project T770, Pb4 and 212.90 kWh/m^{2}year for the standard project 1340. The heating energy for each building built according to the three standard projects are 345700 kWh/year, 405940 kWh/year and 271447 kWh/year which means 100.50 kWh/m^{3}year, 91.53 kWh/m^{3}year and 82.77 kWh/m^{3}year.

4.2. Heating energy demand according to Romanian normative and the heating energy demand of the buildings with bearing structure of large precast concrete panels

In Romania, the thermo technical calculation and the verification of heating energy consumption in the design phase of a building is made according to C107 code which is the Romanian normative on thermo-technical calculation of structural components of buildings (C107, 2005).

The C107 normative establish a maximum value for heating demand depending on the ratio between the envelope area and the heated volume of a building, both for new buildings and for existing ones, as seen in the chart below (figure 4).

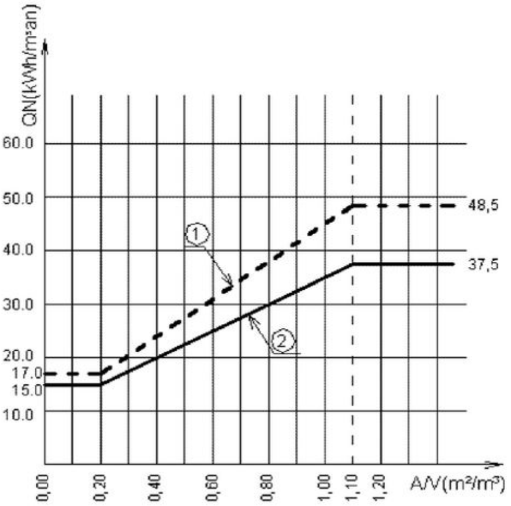

Figure 4. The accepted heating demand values for residential buildings

The line 1 from the chart above represents the accepted heating demand values for residential buildings designed before January 1, 2011 and the line 2 represents the accepted heating demand values for residential buildings designed after January 1, 2011 (NP062, 2002).

It can be seen that the maximum acceptable heating demand value for existing buildings is 48.5 kWh/m^{3}year, therefore the values of heating demand for the analysed buildings built in compliance with the standard projects are higher than the accepted values provided in C107 normative.

In table 4 are presented the heating demand values for the studied buildings, the accepted heating demand values stipulated in C107 normative and the ratios between the envelope area and the heated volume (A/V).

Standard project	Ratio A/V	Heating demand values of studied buildings [kWh/m^{3}year]	Accepted heating demand values [kWh/m^{3}year]
T744, Db1	0.41	100.58	23.00
T770, Pb4	0.43	91.52	25.50
T1340	0.45	82.77	26.00

Table 5. Heating demand values

5. CONCLUSIONS

In Timisoara, more than 60 percent of the inhabitants live in collective buildings. Most of the collective buildings have bearing structure of large precast concrete panels and were built between 1962 and 1992. It is estimated that Timisoara has approximately 3640 buildings with bearing structure of large precast concrete panels which were built using three standard projects: T744-IPCT, T770-IPCT and T1340-IPCT between 1962 and 1992.

The standard projects mentioned above were realised in accordance with the existing normative at that time, which did not take into account energy saving, consequently the elements of the envelope were not provided with good thermal insulation layer. Moreover, after 30 years, the thermal proprieties of the envelope elements, especially the insulation layer proprieties, were affected and the heat losses are increasing.

Nowadays, the energy demands for such buildings are very high and this causes important financial problems for the inhabitants and also political problems for both, local and national authorities.

The total high energy demand is due to the high heating demand. To evaluate the energy demand, first were analysed the geometrical and thermal parameters and then was achieved the energy balance for each standard project. For a more accurate evaluation, was considered an age of 30 years for the analysed buildings.
Following the evaluation, was concluded that the heating energy consumption is responsible for about 75 percent or more from total energy consumption. For example, if the total energy demands for T744 standard project, Db1, is 366.30 kWh/m^2 year, the heating energy demand represents 281.90 kWh/m^{2}year.

The Romanian normative C107 sets maximum values for heating demand. The maximum accepted value is 48.5 kWh/m^{3}year or lower, depending on the ratio between the envelope area and the heated volume. The heating demand values for collective buildings with bearing structure of large precast concrete panels in Timisoara are much higher than the accepted values.

The heating energy for T744 standard project, Db1, is 100.50 kWh/m^{3}year, for T770 standard project, Pb4, is 91.53 kWh/m^{3}year and for T1340 standard project is 82.77 kWh/m^{3}year. The maximum accepted values for this three projects are 23 kWh/m^{3}year, 25.50 kWh/m^{3}year and 26 kWh/m^{3}year.

In the diagram below are presented the actual heating demand values of the analysed buildings in Timisoara compared to the heating demand values set out by the Romanian normative.

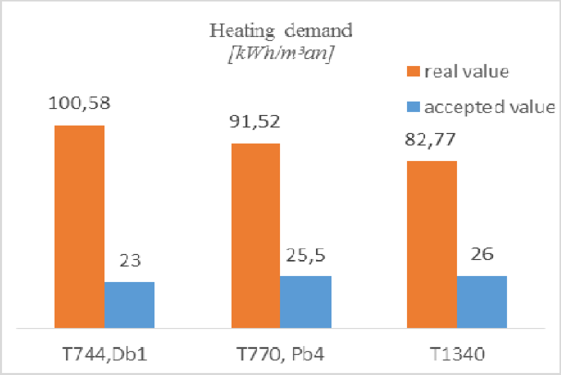

Figure 5. The heating demand values

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