Theoretical and experimental studies regarding the thermal rehabilitation of a student’s hostel

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Abstract: - The student’s hostels located in Timișoara-Romania were mostly built from 1970 to 1980 with the adoption of minimum solutions for the thermal insulation required at the time. The hostels are heated by using a district heating station. The use of the buildings without general repair work has led to the occurrence of certain damages, especially because of the sweat on the walls. The paper presents the situation of one hostel before and after thermal rehabilitation, along with the solutions adopted.

The solutions adopted referred to the improvement of global thermal resistance of the envelope elements in order to reduce the pollution and the energy loss. A comparative study is made between the rehabilitated building using one polystyrene layer, mortar finishing for exterior walls and thermally insulated windows with the same solution but using for windows a new performing material aerogel. The energetic performances and energetic classification are presented for rehabilitated hostel.

Key-Words: - sustainability, thermal insulation, energetic audit, thermograph, aerogel

1 Introduction

The "Politehnica" University of Timisoara, Romania is one of the largest and best-known technical universities in Central and Eastern Europe. Located in Western Romania, the "Politehnica" University attracts students both from the city and form the neighbouring regions.

During the university years, the administration offers students the possibility to find accommodation in the campus. The administration of the University is permanently concerned with the improvement of the accommodation offered to the students, therefore, the investments have been directed especially to the rehabilitation of the students’ hostels. This activity has been carried out during the latest 3 years and the interventions were focused on the reconstruction of the finishing works, as well as the improvement of the comfort conditions. Taking into account the age of the buildings and the installations thereof, the works aimed at the total change of the installations, the complete remaking of the finishing, and the improvement of the thermal insulation and installing of one thermal station for each hostel. One of the students’ hostels that have been rehabilitated is Hostel 20C (Fig.1).

Fig. 1 Main facade of the hostel 20C

The building is included in the accommodation park of the Politehnica University of Timisoara, being erected in 1978. It has a basement, a ground floor and five storeys, each storey hosts ten apartments, and each apartment includes two rooms, a shower room and a water closet. The apartments also have a hallway, with two sinks. On each floor,
at the end of the hallways, there are the stairways and 2 pantries, nowadays also used for students' accommodation, although, in the past, they contained electric cookers or washing machines. The efficiency of existing insulation system is represented in figure 2.

![Fig. 2. The exterior temperature of façade (thermography of façade)](image)

The total surface of the building is about 6566 square meters (out of which the 938 square meters of the technical basement). The surface of one floor is about 938 square meters.

From the point of view of the structure, the hostel has a vertical resistance structure composed by structural reinforced concrete walls made up of large prefabricated panels for the facade walls and cast in place structural reinforced concrete interior walls. The horizontal structure is made of reinforced concrete prefabricated panels. The partition walls between the rooms hallways and the bathrooms respectively the shower rooms are non-structural, made of reinforced light weight concrete blocks. The original roof was initially a terrace-roof. Nowadays, it has a sloping roof.

The roof envelope and the envelope accessories are newer than the building, being built after 1985. The interior finishing of the walls is done with lime mortar coating and clay painting that has to be entirely remade, due to the high level of degradation. On the building side that shows to the park nearby, in several rooms there have been noticed mouldiness caused by the insufficient thermal insulation and to the existing thermal bridge (Figure 3a).

The access hallways to the hostel rooms are partially covered with tiles that show degradation and need to be entirely replaced. The bathrooms also have tiles that are damaged (Figure 3b). The floor of the main hall is covered with cast mosaic or cast mosaic plates.

![a. Mouldiness on the exterior walls b. Degradation of the tiles and piping](image)

Fig. 3. Aspects of the hostel’s status

2 Rehabilitation of the student hostel

Before the rehabilitation of the hostel, there has been performed a technical and thermo-energetic expertise in order to decide upon the intervention measures. From the structural point of view, the building can take both gravitational and horizontal (earthquake) loads. No structural damages have been noticed during the operation along the years. The thermal-energetic expertise aimed at establishing the level of the energetic performances of the existing building and to decide upon the principle solutions for rehabilitation. The heating of the hostel was done by the centralized city system.

The good behaviour in time of the structure led to the lack of imposing special rehabilitation steps. But the proposal to install the hostel’s own heating station required the consolidation of the floor over the basement and the ground level, due to the increased loads brought to the installations. The floor intended to support the boilers of the heating station was made of reinforced prefabricated concrete 9 cm thick, designed for an effective load of 150 daN/m². The structural solution adopted was to build an additional floor over the existing one, the new floor coming with cross beams able to take over the vertical concentrated loads from the equipments and the elements of the station.

2.1 Energetic classification of the existing building

The investigation performed led to the conclusion that exterior envelope elements were built as follows (from the interior to the exterior):

- The side panel, concrete 20 cm, Autoclaved Aerated Concrete 12.5 cm, concrete 6 cm, mortar coating 1.5 cm (Precast Panel Type 1);
- Between the windows: concrete 20 cm, Autoclaved Aerated Concrete 12.5 cm, mortar 0.5 cm (Precast Panel Type 2);
- The bottom panel under the window, concrete 10 cm, Autoclaved Aerated Concrete 12.5 cm, concrete 7.5 cm (Precast Panel Type 3);
- The front walls: concrete 15 cm, Autoclaved Aerated Concrete 12.5 cm, face brick work 7.5 cm (Precast Panel Type 4);
- Double-winged coupled windows;
- Single-wing windows;
- Metallic single-wing doors;
- The flat roof over the fifth storey: concrete 10 cm, vapour barrier made of bituminous membrane of 0.02 cm, autoclaved aerated concrete 12.5 cm, cement flooring 10 cm, waterproof membrane with 5 layers of about 1 cm thick;
- The floor over the basement, linoleum 0.5 cm, 10 cm cement flooring, 10 cm reinforced concrete.

In table 1 are shown the heat flow resistances of the envelope elements, the minimum required resistances and the average thermal resistance of the building.

Table 1. Resistances to heat flow – current situation

<table>
<thead>
<tr>
<th>Element type</th>
<th>( R' )</th>
<th>( R_{\text{ nec}} )</th>
<th>( R )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precast Panel Type 1</td>
<td>0.82</td>
<td>1.4</td>
<td>0.6</td>
</tr>
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<td>Precast Panel Type 2</td>
<td>0.78</td>
<td>1.4</td>
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<tr>
<td>Precast Panel Type 3</td>
<td>0.77</td>
<td>1.4</td>
<td></td>
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<tr>
<td>Precast Panel Type 4</td>
<td>0.9</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Double Coupled Window</td>
<td>0.39</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Simple Window</td>
<td>0.17</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Metallic Door</td>
<td>0.17</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Roof floor</td>
<td>0.87</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>Floor under basement</td>
<td>0.39</td>
<td>1.65</td>
<td></td>
</tr>
</tbody>
</table>

In order to evaluate the energetic classification, there has been calculated the normal annual heat necessary and the normal annual heat necessary for hot water preparation. Based on the values obtained, there was established the energetic classification according to the Romanian codes (Figure 6).

The analysis of the resistance to heat flow obtained after the application of the thermal rehabilitation solutions proved that the resistances to heat flow of the envelope elements exceed the minimum values required, except for the walls of the Eastern and Western facade. Although the solution of the application of a thermo-insulating layer over the interior sides of these walls could be adopted, this has not been done, since the areas neighbouring the non-rehabilitated walls housed the staircase and the common pantries. After the rehabilitation, the average resistance to heat flow of the building doubles.

In order to improve the heating system and to reduce the losses, there has been proposed the

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**2.1 Rehabilitation of the building and energetic classification**

Because all the envelope elements of the building show short-comings regarding the resistance to heat flow, the following measures have been proposed, in order to improve the performances of the building.

Thus, in the first solution studied, concerning the exterior walls there was proposed the execution of a thermal system, composed of an additional thermal protection applied to the exterior, made of polystyrene, over which there is applied a finishing layer on a support of glass fibre. The building will be painted in pastel colours. The existing carpentry will be entirely replaced by plastic carpentry and thermally insulated windows. For architectural reasons, the face brick facades will not be altered, in order to comply with the urban regulations of the area. The floor over the basement will be insulated by the application of a layer of polystyrene 5 cm thick, and the floor over the highest storey will be insulated by the application of a polystyrene layer 10 cm thick and a cement flooring minimum 2 cm thick. Based on the solution proposed, there have been recalculated the resistance to heat flow of the envelope elements respectively the average thermal resistance of the building. The values obtained are shown in Table 2.

Table 2. Resistances to heat flow after rehabilitation

<table>
<thead>
<tr>
<th>Element type</th>
<th>( R' )</th>
<th>( R_{\text{ nec}} )</th>
<th>( R )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precast Panel Type 1</td>
<td>2.17</td>
<td>1.4</td>
<td>1.3</td>
</tr>
<tr>
<td>Precast Panel Type 2</td>
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<tr>
<td>Precast Panel Type 3</td>
<td>2.11</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Precast Panel Type 4</td>
<td>0.9</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Double Coupled Window</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Simple Window</td>
<td>0.5</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Metallic Door</td>
<td>3.49</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>Roof floor</td>
<td>1.65</td>
<td>1.65</td>
<td></td>
</tr>
<tr>
<td>Floor under basement</td>
<td>2.17</td>
<td>1.4</td>
<td></td>
</tr>
</tbody>
</table>

The analysis of the resistance to heat flow obtained after the application of the thermal rehabilitation solutions proved that the resistances to heat flow of the envelope elements exceed the minimum values required, except for the walls of the Eastern and Western facade. Although the solution of the application of a thermo-insulating layer over the interior sides of these walls could be adopted, this has not been done, since the areas neighbouring the non-rehabilitated walls housed the staircase and the common pantries. After the rehabilitation, the average resistance to heat flow of the building doubles.

In order to improve the heating system and to reduce the losses, there has been proposed the
installation of a heating station on gas, the overall replacement of the radiators and the heating system. The proposed pipe lines were made of high density polypropylene, pre-insulated in the basement of the building. Each distribution casing will have devices for evacuation and cleaning. Figure 7 shows the new classification of the thermally rehabilitated building.

Fig. 7. Energetic classification of the Hostel C20 after rehabilitation

The insulated system applied improved the interior comfort, decrease the annual energy consumption, decrease the exterior temperature of the closure elements and eliminated the thermal bridges. The value of the energy consumption for heating is about 62 KWh/m²/year. One recorded isotherm of the main façade is presented in figure 8.

Fig. 8. The isotherm of the main façade after thermal rehabilitation

The aerogels are from the group of solid materials nano-porous – the dimension of aerogel porous it is almost 10nm – the porosity being over 95%, the coefficient of the thermal conductivity $\lambda$ has different values depending on type of aerogel ($0.017-0.007$ W / mK).

Based on the solution proposed, to keep the system for insulation with polystyrene for the opaque walls and to use aerogel for the windows and doors, there have been recalculated the resistance to heat flow of the envelope elements respectively the average thermal resistance of the building. The values obtained are shown in Table 3.

<table>
<thead>
<tr>
<th>Element type</th>
<th>$R'$</th>
<th>$R_{neq}$</th>
<th>$\bar{R}$</th>
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<td>Precast Panel Type 2</td>
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<tr>
<td>Precast Panel Type 3</td>
<td>2.11</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Precast Panel Type 4</td>
<td>0.9</td>
<td>1.4</td>
<td></td>
</tr>
<tr>
<td>Double Coupled Window</td>
<td>1.7</td>
<td>1.7</td>
<td>1.8</td>
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<tr>
<td>Metallic Door</td>
<td>3.49</td>
<td>3.00</td>
<td></td>
</tr>
<tr>
<td>Roof floor</td>
<td>1.65</td>
<td>1.65</td>
<td>1.6</td>
</tr>
<tr>
<td>Floor under basement</td>
<td>2.17</td>
<td>1.4</td>
<td>1.8</td>
</tr>
</tbody>
</table>

Using the new values for the thermal resistance the energetic performances were calculated and the classification of the building is not changed, because the “A” category related to the energy consumption for heating is for the values less than 80 KWh/m²/year. The value of the estimated energy consumption for heating decrease in this case until the value of 38 KWh/m²/year.

The comparison made between the two solutions related to the rehabilitation of windows show in this case no relevant decreasing of consumption related to the cost of the investment in the case of using aerogel for windows. This comparison is made only related to the moment of investment and not represent an evaluation of the life cycle cost.

Due to the common technology and to the prices of thermal insulated windows with plastic frames it was renounced to the ipotetic solution using aerogel for windows.

3 Economical study of the investment

The evaluation of the investment was performed on the basis of the quantity of the determined works according to the proposed interventions. The graphs in Figure 9 show the distribution of the expenses by specialties.

Based on the theoretical evaluations performed, there can be noticed that the thermal rehabilitation led to the reduction of the heat consumption.
necessary for the heating of the area by nearly 50% from the initial consumption. The reduction of the total energy consumption is by more than 50% of the initial consumption. The heat consumption for the heating of the areas reduces because the average thermal resistance of the building doubles and because of the thermal station located within the building, thus reducing the losses along the distribution network.

![Distribution of the investment costs on specialties [%]](image)

**Fig. 9. Distribution of the investment costs on specialties [%]**

The important reduction of the hot water consumption is due to the high efficiency of the thermal station, to the insulation of the distributions pipes and to the installation of timing taps in the shower cabinets. These timing faucets have actually led to a reduction of 40% of the hot water consumption in the whole building. Figure 10 shows the variations of the heating consumption, based on the real data gathered along three years of operation of the building.

![Variations of the heating consumption](image)

**Fig. 10. Variations of the heating consumption**

As is shown in the Figure 11 the heating consumption during the winter decrease with 23% from the values registered before thermal rehabilitation of hostel. Taking into account the total amount of the thermal rehabilitation, that is about 110,000 Euros, and the economy achieved of 2100 Euros/month for heating and hot water, the value of the investment for the thermal rehabilitation is to be amortized in about 6 years.

### 4 Conclusions

Using the results from presented below the following conclusions were formulated:

- the energetic performances of the hostel increase after the intervention, the building became class “B” from class “D”;
- the efficiency of the used insulation system is demonstrated by the reduction of energy consumption and by the values of measured temperature before and after rehabilitation using one thermograph equipment;
- the thermal bridges of the exterior wall were eliminated;
- the using of aerogel for windows is not relevant in this case due to the small ratio between windows surfaces and the opaque surfaces;
- the value of the investment for the thermal rehabilitation is to be amortized in about 6 years.

### References:


