The energy efficiency evaluation on rehabilitated social housing buildings:
Machado Vaz Neighbourhood, Porto - Portugal.

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ABSTRACT: The energy efficiency evaluation as a result of the implementation of rehabilitation works in social housing buildings will be established with the calculation of the two following energy indicators: Global coefficient of heat losses through the building envelope - C(W/ºC) and Gross energy demand for heating - N(kWh). On the rehabilitation of the Machado Vaz Social Housing - this present study case, solar thermal collectors were applicated to the buildings (this was the first housing estate in Portugal equipped with this technology). The installation of solar panel allowed a final energy reduction with the production of domestic hot water throughout the year. At the present study case the energy consumption of two scenarios – pre and post rehabilitation of the buildings- will be presented, also the corresponding domestic hot water production system (AQS (KWh/year)), the savings (€/year) and the CO2 emissions calculation. As a result, it has been verified that despite the total cost of 1.022.654,82 euros of the rehabilitation works on this social housing buildings, an annual improvement of reduction in energy cost of 325.059,33 euros was achieved, which means that this investment will be recovered in a period of less than 4 years.
KEYWORDS: Social housing rehabilitation, Energy efficiency evaluation, "Low cost" social habitation, Solar thermal collectors, Architectural requalification.

1. SOCIAL HOUSING IN THE CITY OF PORTO

This paper attempts to put in evidence the architectural and engineering interventions in rehabilitation of social housing quarters, in order to solve the crucial problems detected (condensation, humidity).

Around the two important metropolitan areas (Lisbon and Porto) it was verified that over than 20% of people live in social housing. A large number of these buildings have an intensive residential use and need a systematic maintenance that is often ignored for economic reasons and also for insufficient planning (Abrantes, 2009).

Thus, the rehabilitation of social housing quarters is undertaken with the purpose of answering to three central questions:

- To solve the existing anomalies that are often caused by rain water infiltrations through the vertical's building envelope, through the roof and through existing cracks in the facades, together with the condensation caused by the lack of insulation and poor existent ventilation.
- To increase the satisfaction and self-esteem of the residents, promoting a modern and higher architectural quality in social quarters.
- To improve thermal comfort and to increase the energy efficiency of the buildings.

As example, two solutions taken from authors' projects, regarding the rehabilitation of social housing quarters, are presented, having in mind that the EU program of investment forces that the housing after the rehabilitation reach more two levels (Abrantes, 2010).

At the present time, the analysis of Santa Luzia Neighbourhood, Porto (Fig. 1, 2 and 3), and its redevelopment project, allowed to study the factors that compromise the urban integration and how the requalification met such conditions.

The project seeks to understand the relationships between the different spatial components in shaping the urban neighbourhood form and the contribution of each of these components to the overall quality of the intervention (Abrantes et Al., 2018).

Each component of the urban space has been designed so that the assembly formed by the new reclassified zones of the design, could be understood as a unit - and not the current sum of road sections, with more or less dispersed buildings and some voids between both, building an urban fabric.

Figure 1:
Santa Luzia Neighbourhood, Porto (640 dwellings). Before rehabilitation.

Figure 2:
Santa Luzia Neighbourhood, Porto. After the architectural and engineering rehabilitation.

Figure 3:
Santa Luzia Neighbourhood, Porto. After the architectural and engineering rehabilitation.

Regarding a second example - the Vila d'Este Neighbourhood, the analysis of the morphological characteristics of this Neighbourhood in two stages (before and after the physical rehabilitation), allowed us to study the factors that compromised the urban integration, the architectural quality and the residents' satisfaction (Fig. 4, 5).

Figure 4:
Vila d'Este Neighbourhood, Vila Nova de Gaia (2085 dwellings). Before rehabilitation.

The redevelopment meets the full range of objectives which must meet the physical rehabilitation of public space in affordable housing sets. Like in the previous case, each element of the urban space was designed together with all other elements, so that all the parts reformulated in the rehabilitation work can be seen as a unit.

Before upgrading, urban set was only a sum of empty spaces between buildings scattered and fairly disjointed road sections, buildings without quality.

In both examples we can see a big improvement of the architectural design with new energy solutions (Fig. 2, 3 and 5).

Figure 5:
The rehabilitation of Vila d'Este Neighbourhood - Ssome energy solutions have been integrated in the new design of facades.

2. MACHADO VAZ NEIGHBOURHOOD, PORTO. - CASE STUDY.

The present study case concerns one of the urbanizations of "low cost" social residence in the city of Porto, with great visibility and localization next to the North-South highway – the Machado Vaz Neighbourhood (Fig. 6 and 7). Built in 1966, the neighbourhood is a large estate with thirteen blocks comprising two hundred and seventy-two units.

This improvement will positively affect not only its inhabitants and users but also visitors, improving their quality of life and, of course, the urban landscape.

The studied part of the urbanization includes 13 buildings corresponding to 256 dwellings.

Figure 6:
The Machado Vaz Neighbourhood, Porto. Before the architectural and engineering rehabilitation.

Figure 7:
The Machado Vaz Neighbourhood, Porto. Before the architectural and engineering rehabilitation.

For each dwelling, a complete inquiry has been undertaken, followed by planned technical visits to those buildings that presented the major anomalies. The purpose was the diagnosis of these buildings, identifying problems and causes, in order to later reach efficient treatment solutions.

In these 13 buildings we present, 6 have an Northwest/Southeast orientation and 7 have an North East/South-west orientation. There are 3 main size windows: bedrooms - 1,10 m x 1,10 m, living rooms - 2,70 m × 2,0 m; bathrooms - 0,60 m × 0,60 m.

The roof is in tile. and the walls façade are a unique wall of stone. The windows have window frames in wood and single glass.

It is important to note that the integration of the architectural component in rehabilitation must be considered as a major and significant value in the image and functionality of the rehabilitated buildings. It is to be expected that the architectural component of valorisation work will be the key for the acceptance of inhabitants and users of the buildings and therefore it induces self-esteem in people to reinforce their bond with their surroundings. This point constitutes a value that must be assured for all social residences (Abrantes, 2021).

Portuguese social residences are subject to the controlled-costs construction regime for social housing. In what concerns to the present study case, the rehabilitation process was promoted by DomusSocial Municipal Company, in 2017. Next, the main rehabilitation procedures are presented (Fig. 8, 9, 10 and 11):

1. Requalification of the façades with the application of Thin Synthetic Reinforced Coating;
2. Replacing the structure and ceramic cladding of the roofs;
3. Replacing the exterior frames (Fig. 10 and 11);
4. Enclosing the stairwells (Fig. 10 and 11);
5. Treating and requalifying entrance/ staircase surfaces, namely walls and floors;
6. Increasing the unit's ventilation systems;
7. Reformulating the structure of the communal areas to comply with current demands: water, supply, rainwater drainage, electricity, telecoms and cable tv;
8. Installing gas supply infrastructure;
9. Installing solar panels (the first housing estate in Portugal equipped with this technology) (Fig. 9).

Figure 8:
The Machado Vaz Neighbourhood, Porto. After the architectural and engineering rehabilitation.

Figure 9:
Solar panels at Machado Vaz Neighbourhood (after the architectural and engineering rehabilitation).

As regards the buildings´s architectural requalification I would highlight the proposal to close the communal stairwell area with an iron structure at ground level, including a stainless-steel door, laminated safety glass and letter boxes.

On the upper storeys the wells were closed on the front part with windows and on the sides with iron grids (Fig. 10).

The clothes drying areas were enclosed with glass brick walls serving as the base for a ventilation frame and grid with a diffuser for future connection to gas and water heaters (Fig. 11).

Figure 10:
The Machado Vaz Neighbourhood (after the architectural and engineering rehabilitation).

Figure 11:
The Machado Vaz Neighbourhood (after the architectural and engineering rehabilitation).

Also, part of the estate´s exterior areas were requalified to serve as a leisure area and small games field (Fig. 12).

My fundamental thesis is grounded in the fact that I believe human beings and buildings reveal similar behaviour, particularly with regard to pathology.

Pathology is defined as the study of diseases, it comes from Greek pathos - suffering, disease, and logia - science, study of.

I would even venture to affirm that both human beings and buildings are born, they live and they die (Abrantes, 2019).

According to Jean de la Bruyère (a 17th century French philosopher) "There are only three events in a man's life: birth, life and death; he is not conscious of being born, he dies in pain and he forgets to live." I underline "he forgets to live" because it will be decisive for pathology.

Figure 12:
The Machado Vaz Neighbourhood (after the architectural and engineering rehabilitation).

3. ENERGY EFFICIENCY EVALUATION

As a result of the implementation of rehabilitation works in social housing, the energy efficiency evaluation is established with the calculation of the two following energy indicators (Decreto-Lei nº 118/2013, 2021):

1. Global coefficient of heat losses through the building envelope - C(W/ºC), given by the following equation (1):

$$C = \sum U_x \,.\, A_x \qquad (1)$$

where U_x – Coefficient of thermal transmission of the blank and glazed facades and of the roof [W/m²ºC].

A_x – Area of blank and glazed facades and of roof [W/m²ºC].

2. Gross energy demand for heating - N(kWh), given by the following equation (2):

$$N = C \,.\, GD \,.\, 0{,}024 \qquad (2)$$

Where GD - Heating degree days on a basis of 20 ºC (ºC.day).

Regarding the rehabilitation of the present study case - the Machado Vaz Social Housing - solar thermal panels were integrated in the buildings (as mention before, this was a pilot intervention where for the first time, a housing estate in Portugal has been equipped with this technology) (Fig. 13). Considering the production of domestic hot water throughout the year, it was found that the installation of solar panels allowed a final significant energy reduction.

Table 1 presents the estimated cost of the rehabilitation works associated with this intervention and which had energy efficiency-direct effects.

Table 1:
Cost of the rehabilitation works

Works	Quantities	Unit Cost	Total Cost
Facades	6792.88m²	26,02 €/m²	176.750,74 €
Roof	4003.50m²	74,17 €/m²	296.939,60 €
Glazed Areas	2043.89m²	189,43 €/m²	387.174,08 €
Regulating Grids	680un	3,88 €/u	2638,40 €
Solar Panels	146un	766,16 €/u	111.859,36 €
"Storage"	272un	173,87 €/u	47.292,64 €
			1.022.654,82 €

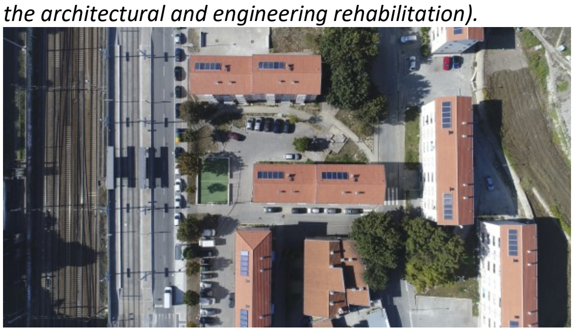
We calculate that the saves are 325.059,33 € per year and the energy consume reduction is 58,25 % per year.

Table 2 presentes the energy consumption of the two scenarios – the pre and post rehabilitation of the buildings – together with the corresponding domestic hot water production system (AQS (KWh/year)), the savings (€/year) and the CO2 emissions calculation (Table 2).

Table 2:
Pre and post rehabilitation scenarios

Rehabilitation Scenarios	Energy (KWh/year)	(€/year)	(Ton CO_2/year)
Pre-Rehab.	2.749.468	558.004,53	395.92
Post-Rehab.	1.147.796	232.945,20	165.28
Savings	1.601.672	325.059,33	230.64
Reduction (%)	58,25 %	58,25 %	58,25 %

Figure 13:
Solar panels view at Machado Vaz Neighbourhood (after the architectural and engineering rehabilitation).



4. CONCLUSION

The three presented interventions focusing the rehabilitation of social housing quarters show how we can solve, in an easy integrated manner, the lack of energy efficiency through technical engineering solutions.

These solutions combined with architectural interventions and the redesign of the buildings will increase the satisfaction and self-esteem of the residents, at the same time qualifying the urban integration of the quarters.

It is important to refer that the integration of the architectural component in rehabilitation must be considered as a major and significant value in the image and functionality final result of the rehabilitated buildings (Efficient Buildings).

It is to expect that the architectural component valorisation work will be the key for the acceptance of inhabitants and users of the buildings and therefore it induces auto-esteem in people to reinforce their bound with their surroundings. This point is, without any doubt, a value that must be assured for all social residence areas (Project X-tendo, 2020).

At the present study case, it has been verified that the rehabilitation works on this social housing buildings had a total cost of 1.022.654,82 euros, but having an annual improvement of reduction in energy cost of 325.059,33 euros, which means that this investment will be recovered in a period of less than 4 years (iBRoad project, Horizon 2020).

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