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Energy Saving Building Management

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Abstract

This research paper shall present the state of building stock in the Republic of Croatia from the viewpoint of its thermal quality and energy saving possibilities. The analysis of technical solutions for improving thermal quality of a typical housing building built in the second half of the 20th century will also be outlined together with the analysis of the costs and profits of such an renovation. The research paper also displays technical regulations regarding the energy saving, the governmental and institutional attempts to stimulate and implement such technical interventions, as well as the analysis of problems encountered during such implementation.

Key words

Thermal quality of buildings, costs, energy savings, institutional stimulations

1. Introduction

The state of building stock in the Republic of Croatia shall be described regarding its state of maintenance (Katavić, et al, 1999). It is important to state the following facts: the public ownership of flats in Croatia lasted for many decades and it caused a low-grade maintenance of buildings; in the beginning of the 1990-ies, the transition to private ownership with development of appertaining regulations occurred. One of the consequences of improper maintenance and lack of investments in renovations of buildings is also a poor energy quality of Croatian building stock. Although flats are now privately owned, their thermal characteristics influence the total energy consumption for heating and air conditioning and indirectly the environment, both being social problems. Therefore, management of buildings regarding thermal protection should be one of the society's priorities in stimulating the sustainable development.

2. Description of the Building Stock

In order to look into basic characteristics of buildings in the Republic of Croatia from the viewpoint of their thermal qualities, a division has been made on the basis of their construction date, producing three important groups: buildings constructed before 1930, buildings built between 1930 and 1970 and buildings constructed after 1970 up to the present.

Buildings constructed before and up to 1930 were mostly built out of bricks or stone (depending on the region). Thickness of walls is from 40 to 120 cm. Ceilings are mostly wooden or massive, made or bricks or stone. This group of buildings used to fulfil the energy saving requirements of the time in which it was built, as a result of wall thickness and low heating standards of premises. Today, tenants of such buildings confront the problem of greater energy losses, due to higher standards of heating, as a result of inadequate heat insulation and commonly non-existent or inadequate humidity insulation, causing damping of walls and premises. It is estimated that out of the total number of buildings in the Republic of Croatia, there are 17% of those built in the above mentioned period.

Buildings erected in the period between 1930 and 1970 are characterized by construction systems made of concrete and reinforced concrete, with performed structural analysis regarding exclusively vertical forces (i.e. not taking into account dangers caused by earthquake), but without application of energy calculations and energy protection systems. Today, such buildings suffer from great heating energy losses and as a result of the heat bridge, humidity and mould occurrence, they are not hygienically convenient. Out of the total number of buildings in the Republic of Croatia, there are 35% of those built in the above mentioned period.

The first regulations for heat insulation of buildings were introduced in 1970. They required the application of insulation materials 3-4 cm thick on the building's superficies. It is estimated that out of the total number of buildings in the Republic of Croatia, 27 % of the existing flats were built in this period. By regulations introduced in 1980, requirements for application of insulation materials were increased to 5-6 cm, and after 1987 the thickness of this insulation increased up to 12 cm. It is estimated that out of the total number of flats in the Republic of Croatia, 21% were built after 1980.

Table 1 is presenting the allowed thermal conductance k for three climatic zones existing in the Republic of Croatia and for individual buildings' construction elements.

Table 1: Maximum allowed thermal conductance k [W/m^2 K] according to standard HRN U.J5.600

Construction element	k [W/m^2 K]					
	Standard: HRN U.J5.600			Estimate for the building as a whole		
	Construction climatic zone			Construction climatic zone		
	I.	II.	III.	I	II	III
Outer walls	1,20	0,90	0,80	0,90	0,60	0,50
Floor on the ground	0,90	0,75	0,65	0,70	0,50	0,50
Ceiling towards the attic	0,95	0,80	0,70	0,60	0,40	0,35
Ceiling above the basement	0,75	0,60	0,50	0,70	0,50	0,45
Ceiling above open passages	0,50	0,44	0,40	0,50	0,40	0,35
Sloping and flat roofs	0,75	0,65	0,55	0,50	0,35	0,35

According to regulations from 1987, heat losses are being limited not only for individual construction elements, but also for the building as a whole. Therefore, thermal conductance of individual construction elements have to be significantly lower than values stated in Table 1 according to standard HRN U.J5.600, allowing different combinations of values of thermal conductance. The average estimated values of coefficient k are also given in Table 1, that fulfil the additional requirement for limitation of total heat losses of the whole building. The stated data are calculated for a four-floor-building with several flats.

In terms of manner and quality of flats' heating, the available data show that central heating is installed only in 25% of flats, while the remaining 75% are room-heated. Furthermore, it is also estimated that the percentage of heated surfaces in flats that are central-heated is around 47%, while in room-heated flats this percentage is 25%.

We can conclude that an important characteristic of the existing building stock in the Republic of Croatia is a large portion of old flats, i.e. flats with adverse properties regarding energy protection and that their number constitutes more than 50% of the total number of flats. Next to this fact, one should bear in mind the estimate of energy needs' increase caused by the alteration of the heated surface percentage, which is expected to grow significantly. Both stated factors indicate the need for finding technical solutions in order to increase the buildings' energy efficiency and the need for testing the cost-effectiveness of such action.

3. Case Study

In order to analyse technological possibilities and to test investment effects in value in renovation of buildings' heat characteristics, an analysis has been made and a selection of the most favourable variant on the example of the existing five-floor-building in the new part of the city of Zagreb, build in the late 1960-ies. Precisely this building was chosen, because it represents a typical construction of that era in its concept and features, and it represents a group of buildings that are most numerous in the total building stock of the Republic of Croatia (note paragraph 2).

3.1 Description of the sample

The analysed building is freestanding, containing 51 flats and flats are organized around three staircase. On each floor there are three flats on one stairway. Flats range from two-room-flats to four-room-flats. The construction is a combination of the structural reinforced concrete walls and brick walls. The roof is flat, protected by humidity insulation without heat insulation. Facades are also without heat insulation. Building windows are wooden, double-glazed, and on the staircase single-glazed. The existing openings on the building are windows and French windows, and they are equal in dimensions and arrangement on the northern and on the southern front. The state of the fronts, windows and generally all finishing works on the building is bad and requires sanation and renovation. This building is one of many identical ones in this part of town, constructed in the same time, and of the same maintenance level.

3.2 Description of the intervention

The hypothetic technical intervention on the building should have for its goal renovation of the worn-out parts of the building, with renovation of the building's heat characteristics. Interventions should include the whole building's superficies, i.e. the roof, windows included, walls of the staircase, and visible foundations' parts.

In the present condition, outer walls consist of 2 cm of the inner plaster, brick wall which is 38 cm thick and outer plaster which is 3 cm thick. The intervention is analysed as a possible combination of two variants of technical solutions. The first variant is the ventilated front, with thermal insulation and layer of air that is paved with ceramic tiles. The other variant of the intervention is the contact front, i.e. such front where thermal insulation is attached to the wall, and a metal net is installed on top of it, and then plaster is applied in layers. Both solutions are common in the present construction practice. Next to both solutions of walls' renovation, a change of all windows is understood, which are presently wooden, double, without rolling shutters and installation of plastic windows is envisaged, with insulation glasses and rolling shutters. Besides, since in the present state both the northern and the southern front of the building are the same, a reconstruction of wall openings is intended. On the southern front, where windows are, openings in the wall should be made and French windows should be installed, while in the northern front the existing French windows should be replaced by the common windows and parapet should be closed by bricks.

In the present state, the roof has no thermal insulation but it consists of 1,5 cm of inner plaster, 14 cm of reinforced concrete construction and humidity insulation on the whole surface of the roof, so that tenants living in the highest floor feel high temperatures in the summer, i.e. low temperatures in the winter. The repair of the roof is also analysed in two variants. Both variants use thermal insulation materials and the difference between variants makes different order of layers and the final layer which is in one variant PVC roof ribbon and in the other small pebbles. Next to both of those variants, a change of the total rooftop and front tinwork is envisaged.

The staircase wall in the present state consists of 2cm of plaster towards the flats, brick wall 25 cm thick, and plaster towards the staircase 2cm thick. The repair is envisaged as follows: the wall should be layered on the surface toward the staircase with a heat insulating material which is 9 cm thick and plastered afterwards.

The wall of the foundations in the present state consists of reinforced concrete wall 50 cm high above ground, to which outer side a layer of bitumen coat and stone plaster. Renovation is anticipated as follows: on the outer wall surface a multi-layer bitumen humidity insulation should has to be set, and on top of it a layer of extrudated polystyrene 4 cm thick. As the final layer, the stone plaster is set, 3 cm thick. On the outer side of the foundations under the soil, after extrudated polystyrene, a drainage is set.

In technical and cost-effective sense it is envisaged as a part of the intervention to perform works on renovation of inner premises after devastation caused by the previous works. The stated works include parquet floor repair and varnishing in the intervention zone.

3.3 Thermal insulation effects

Verification of construction elements with regard to heat characteristics is performed in accordance with positive rules for walls, roof, staircase wall and base of the building in the existing state and in the anticipated new state. Calculations were performed for the continental climatic zone with presuppositions that air temperature in the premises are 20°C in the winter and the relative air humidity is 60%. Calculations have shown that all elements of the existing construction are not satisfactory at least in some of the heat conditions' aspects, and the verification of a new condition showed satisfactory results for each individual element of all variants, and for the building as a whole. The comparison of average values of the thermal conductance for different variants in relation to the existing state is given in Table 2.

Table 2: Comparison of average values of the thermal conductance k [W/m^{2}K]

Variant	Description of the variant	k [W/m^{2}K]	k of the new state / k of the existing state
1.	Front: ceramic tiles – Roof: PVC foil	0,85	0,43
2.	Front: ceramic tiles – Roof: small pebbles	0,86	0,43
3.	Front: contact – Roof: PVC foil	0,81	0,41
4.	Front: contact – Roof: small pebbles	0,82	0,42
Existing state		1,96	1,00

We can conclude that the hypothetic intervention in each of the analysed variants would lower the thermal conductance to the value lower than half of its value in the state before repair.

3.4 Estimate of the intervention's financial effects

The estimate of intervention's financial effect is performed as follows: the costs of the building's repair are put into relation with estimated heating savings in the winter months and finally a refund of invested means for each analysed variants of the technical solution is estimated. Repair work costs were estimated in Euros on the basis of construction works' costs present on the market of the Republic of Croatia. The price of the whole intervention is approximately between EUR 168.000,00 and EUR 206.000,00 depending on the applied repair variant. Energy savings, resulting from decreased needs for heating in the winter period is estimated with help of the empirical formula:

$$\mathbf{U = k*10\ (5)}\ [m^3 \text{ of gas} / m^2 \text{ outer element} / \text{per annum}]$$

Whereas : **U** – energy consumption in a m^3 of gas
k – coefficient of heat conductivity
10 – multiplier for surfaces exposed to the atmosphere (outer walls and roof)
5 – multiplier for protected surfaces (staircase walls and floor to the ground)

Comparison of energy savings and costs is given in Table 3.

Table 3: Comparison of costs and energy savings

Variant	Description of the variant	Total value of the intervention [EUR]	Annual energy savings [EUR/year]	Time of invested means' refund [yrs]
1.	Front: ceramic tiles – Roof: PVC foil	202.985,73	6.655,06	31
2.	Front: ceramic tiles – Roof: small pebbles	168.247,73	7.812,39	22
3.	Front: contact – Roof: PVC foil	206.180,47	8.213,06	25
4.	Front: contact – Roof: small pebbles	171.442,40	8.116,66	21

As it is visible from the Table 3, the time of refund of means invested in the renovation of the building's energy characteristics would be 20 years for the most favourable variant. We can conclude that invested means' refund period, for interventions improving the building's energy characteristics is shorter than duration period of the installed elements and works performed with such aim. This means that energy savings pays off the complete value of works, i.e. after a definite period provides also certain profits. Out of this reason, the investment in the stated works may be considered efficient. To the direct financial effects of the investment we should also add those that are indirect, like energy savings, protection of the environment, raising of the quality and comfort of the residential premises, prolongation of the building's duration etc.

4. Regulations and Society's Incentives

Regulations and social activities with regard to energy preservation and upgrading the buildings' energy characteristics can be divided into those relating to new buildings and those relating to the existing building stock.

For new buildings a regulation is in force, according to which it is obligatory to perform calculation of thermal transmission coefficient k, calculation of steam diffusion and calculation of heat stability for the summer period for all buildings of a surface larger than $500m^2$ and which are heated to the temperature beyond +12°C. For the same buildings it is necessary to perform revision of the main project, testing the correctness of the heat protection concept, correctness of the applied methods of calculation, application of technical regulations and correctness of the heating system, cooling system, ventilation and air conditioning from the viewpoint of the rational usage of energy.

For older buildings, i.e. those that were built according to some of older technical regulations or before 1970, i.e. before first regulations concerning buildings' heat protection came into force, there are no standards defining the manner of their adaptation to the positive regulations. This means that when buildings are exploited, maintained, improved and reconstructed, in the rule no harmonization is requested in the field of energy protection.

On the other hand, since 2002, a state programme exists, for financing the reconstruction of buildings' fronts on credit with very favourable conditions of instalment payments. In case that concept presented in this work should be applied, it is visible that such investment would be cost-effective. However, experience shows that tenants very rarely decide to apply this model. Reasons for this are the social status of tenants, for which a credit with interest significantly lower than market interest is still too great of a burden, but also a relationship towards the flat itself. Even after privatisation, many people still tend not to consider it to be their own property, which needs to be maintained and invested into.

One of the reasons for non-application of buildings' renovations in thermal quality to a larger extent also a lack of knowledge by tenants, building owners and even constructors about realistic possibilities of application of such renovations and of their real cost-effectiveness.

5. Conclusion

We can conclude that it would be interesting to perform the analysis carried out in this work on a sample extended by buildings with different thermal characteristics. It would also analyse different technologies of improvement of buildings' thermal characteristics. Furthermore, a similar type of research should be performed for heating and air conditioning systems, which are presumed not to be in optimum condition. Finally, we consider that analyses like this should form a part of the total programme of improvement of energy efficiency in building construction, which should be very open to expert public and users, with aim of optimal and sustainable management of the building stock, which is largely not adequate heating-wise.

6. References

1. Bureau for Development Strategy of the Republic of Croatia: Energetics – Strategy of Development of Energetics, Energy Institute Hrvoje Požar, Zagreb, Croatia, 1998.
2. M.Katavić, I.Završki, A.Cerić: Sustainable Maintenance in Transition Economies, Proceedings of CIB World Building Congress 1998, Managing Sustainability - Construction and Environment, Gavle, Sweden, 1999 pp 1871-1878.

3. M.Katavić, I.Završki, A.Cerić: Maintenance Problems in the Republic of Croatia, Proceedings of International Workshop on Information Support for Building Economics, Salford, United Kingdom, 1997, pp 55-64
4. M.Katavić, I.Završki, A.Cerić: Information System in Building Maintenance, Proceedings of the 8th International Symposium on Information Systems 1997, Varaždin, Croatia, 1997, pp 207-212
5. Energy Institute Hrvoje Požar: Kuen building – Programme of Energy Efficiency in Building Construction, Energy Institute Hrvoje Požar, Zagreb, Croatia, 1998.