Energy Efficiency Improvement of Cultural Heritage Buildings: Problems and Challenges of Modern Movement Public Buildings

Iva Muraj, Ph.D.Arh; Zoran Versic, M.Sc.Arch.; Dunja Mandic, Dipl.Eng.Arh.
Faculty of Architecture
University of Zagreb
e–mail: iva.muraj@arhitekt.hr; zoran.versic@arhitekt.hr; dunja.mandic@arhitekt.hr

ABSTRACT

The great energy-saving potential for renovation are public buildings constructed between 1930 and 1940. The energy index of modern movement public buildings is much higher in comparison to today's standard for new houses. Current building regulations seek to improve the energy performance of all buildings, including existing ones, when altered and upgraded. Better energy efficiency can be achieved only by physical change to the building fabric. Differences in applying renovation measures result from the level of building conservation. Improvements to the building envelope, especially the introduction of thermal insulation measures, can be particularly difficult for architecturally important buildings and some alterations are often impossible to carry out without impact to the historic fabric.

Keywords

Modern movement architecture, public buildings, building physics, energy balance

ENERGY EFFICIENCY CONSERVATION OF MODERN MOVEMENT ARCHITECTURAL HERITAGE

Many countries have set ambitious goals to strongly reduce CO_2 emissions by the year 2020. There is an enormous saving potential in the public buildings area. Restoration measures, which save energy, can significantly reduce heating cost. Current building regulations seek to improve the energy performance of all buildings, including existing ones, when altered and upgraded. Conditions and requirements in terms of building physics and climate present new challenges in the practice of heritage conservation.

Protection and conservation of Modern movement architectural heritage is a part of the general theory and practice of conservation of architectural heritage. In decisions on how best to incorporate a renewable technology, the principles of minimum intervention and reversibility should be adopted. Retaining existing elements of construction in historic buildings and seeking to enhance their thermal performance in benign ways is a heritage conservation principle in line with the concept of sustainability. The majority of historic buildings can accommodate some improvements to the building envelope.

Modern architectural form is always simple, rational, functional, characterized by pure white walls, flat roofs, without "unnecessary" details. Eighty years after they were built, it is unavoidable that many building components and interior fittings are worn out. They no longer satisfy contemporary standards so architects meet a lot of problems and challenges while renovating. Prior to renovation, a comprehensive study of the interaction between architecture, function, structure and building climate is needed. Economic constraints and restrictions to preserve historical buildings considerably limit what is possible, so a reasonable compromise between thermal insulation, living comfort and the available means must be found.

RESEARCH MODEL: PUBLIC BUILDINGS IN ZAGREB DESIGNED BY ARCHITECT EGON STEINMANN

This paper takes a look at public buildings in Zagreb designed by Egon Steinmann (Karlovac, 1901- Zagreb, 1966) built between the Two World Wars. His major public and residential buildings were constructed in Zagreb: the Orthopaedic and Dental Clinic of the Medical Faculty on Salata in Zagreb (1929), secondary school building in Krizaniceva Street (1930), Gym hall and Sokol sports hall in Kaciceva Street (1933), secondary school building in Kuslanova Street (1934), residential block for savings bank post-office workers in Petrova Street (1937) and the Post Office II in Branimirova Street (1939). Steinmann was educated in Zagreb at the architectural department of the High Royal Technical School (1920-1924), and was employed for 20 years as the architect of the Technical Department of Savska Banovina [1].

The starting point for this paper were three chosen public buildings (Figure 1): Orthopaedic Clinic on Salata (1929), School building in Krizaniceva Street (1930) and Sports hall in Kaciceva Street (1933).

Orthopaedic Clinic on Salata School in Krizaniceva Street Sports hall in Kaciceva Street

Figure 1. Public buildings designed by architect Egon Steinmann in Zagreb: Orthopaedic Clinic on Salata, School in Krizaniceva Street and Sports hall in Kaciceva Street, building appearance comparison: after construction and current state

The buildings are functioning well, continuously from the moment of their erection and presenting a recognizable individual architectural work of interwar Modern movement architecture. Throughout the years they haven't been adequately renovated and maintained. Over the years buildings have undergone several changes and alteration but the original state of buildings from 1930ies remained almost unchanged. Buildings are situated in the centre of Zagreb in the protected zone A or B. School in Krizaniceva Street is evaluated as registered cultural heritage. Two buildings (hospital and school) have a residential basement, ground floor, two or three floors, and residential attic with pitched roof (Figure 2). Compact housing blocks constructed as massive (brick) walls, symmetrically composed consist of a rich repertoire of openings, porches, balconies, terraces and rounded volumes. The small sports hall with flat roofs was exposed to many controlled and uncontrolled addings. It was built with frame reinforced concrete loadbearing structure filled up with brick but without thermal protection. The sports hall was partialy renovated 2005.

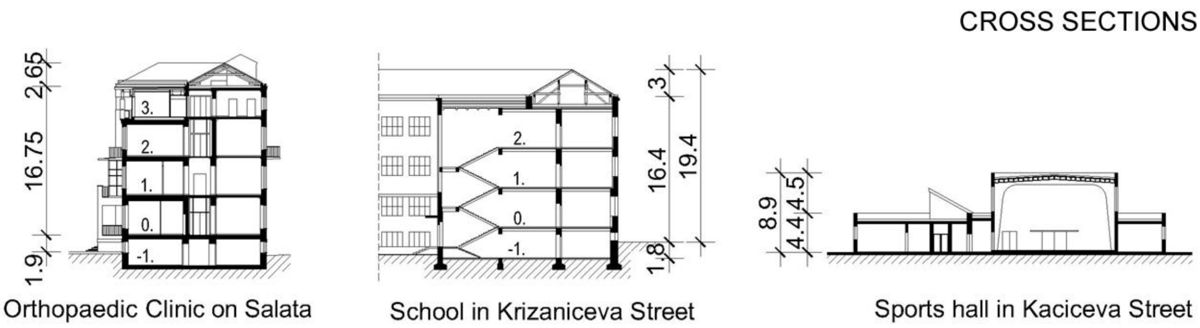

Figure 2. Public buildings designed by architect Egon Steinmann in Zagreb: Orthopaedic Clinic on Salata, School in Krizaniceva Street and Sports hall in Kaciceva Street, cross sections

Current Energy Consumption

In the area of thermal protection and energy saving in buildings numerous European standards were accepted during the last years in Croatia. Technical Regulation on Thermal Energy Savings and Thermal Protection of Buildings introduced new calculation method for energy performance denoted as the annual thermal heat demand necessary for the heating of the building (Qh'). The survey of structural conditions of three public buildings showed that the energy index is much higher in comparison to today's standard for new houses.

The approximate calculation of thermal losses[1] of selected building showed that [2]: Specific transmission heat loss is 36-92,50% higher than quotas set for specific transmission thermal loss. Annual thermal heat demand needed for heating is 60-103% higher than annual set quotas for heat demand needed for heating (Table 1).

[1] The used calculation method was done 2005 according to Technical Regulation on Thermal Energy Savings and Thermal Protection of Buildings (OG No. 79/05). The calculation method focused on the heat necessary for space heating in buildings was based solely on the construction part of the building without taking into consideration the efficiency impact of heating, air-conditioning and ventilation systems and does not present the actual energy consumption.

Table 1. Energy consumption of three chosen public buildings in Zagreb and the ratio (%) between allowed and current parameters

Energy consumption of three chosen public buildings designed by Egon Steinmann in Zagreb						
CURRENT STATE OF THREE CHOSEN PUBLIC BUILDINGS	allowed Ht' - specific transmission heat loss W/m^2K	current Ht' - specific transmission heat loss W/m^2K	ratio (%)	allowed Qh' - annual thermal heat demand kWh/m^3a	current Qh' - annual thermal heat demand kWh/m^3a	ratio (%)
Orthopaedic Clinic	0,85	1,50	76,5	17,63	35,77	103
School in Krizaniceva	0,66	1,27	92,5	20,07	38,50	92
Sports hall in Kaciceva	0,58	0,79	36	21,95	34,95	60

The structure of building construction and materials of external building envelope do not correspond current regulations. The problem of heat flow through the outer building envelope is the physical and structural key problem of the inter war period buildings built mainly without thermal insulation. Building construction parts do not fulfill the standardized requirements for overall heat transfer coefficient (U-value) for heated buildings ≥18°C.

PROPOSED THERMAL IMPROVEMENTS

The renovation of historical buildings is frequently faced with the challenge of how to improve the thermal insulation levels of old structures effectively and simply. Till today there has been no method available which offers a technically satisfactory solution to this problem without noticeably changing the appearance of the building.
This project proposed thermal insulation of building envelope introducing minimal insulation of building construction parts. Suggested thickness of thermal insulation is: walls (outside 8-10 cm, inside 4-8 cm), floors (10-12 cm), roofs (12-16 cm) and windows $U<1,8\ W/m^2K$.
This project suggested thermal improvements to the building envelope divided into three steps: 1. Improving thermal performance of basements, floors and roofs, 2. Improving walls insulation and 3. Improving window insulation.

1. Improving Thermal Performance of Basements, Floors And Roofs

From the outside these renovation measures are not visible and can be applied independently from other measures. The heat requirement can be reduced by insulating the unheated attic ceiling (by adding the insulation layer i.e. expanded polystyrene EPS or mineral wool MW: 12 cm). If the basement is used, the thermal performance of floors (EPS: 10 cm) and walls (XPS: 10 cm), contribute reducing heat loss. In order to attain a satisfactory heat loss limitation level thermal insulation should be also applied in the unheated basement ceiling (MW: 12 cm). Thermal insulation should be also applied in the roof construction (by adding the insulation layer in flat roofs - EPS: 12 cm and in pitched roofs (MW: 10 cm).

Through complete conversion of the attic floor, through insulation of basement walls and ceiling, and roofs, heat loss and annual thermal heat demand can be reduced by 13,50-32% in relation to current state.

2. Improving Walls Insulation (externally/internally)

The facade is the face of a building. It has the major share in the appearance and impact of a building. This project is based on basic principles of facade thermal renovation. Rendered facades are used on solid walls and usually the rendered thermal insulation layer is attached to external structure (i.d. compact system with thermal insulation of expanded polystyrene /EPS: 8-10 cm/). Often this measure is limited in historic building because of the impact external insulation has on the appearance of the building (dimensional differences, proportions, details etc.). The building can't meet the present-day technical regulation without applying the suggested measures because most heat is lost through external walls.

With additional insulation of exterior walls, and along with step I., almost 21,50-36,50% heat loss and annual thermal heat demand can be reduced in relation to current state.

The proposed thermal insulation can be attached on inner surfaces of external structures. This principle is used when outer changes are not allowed because of historical value of the building. Out of three chosen public buildings, only the school building in Krizaniceva Street is listed on the National Register of Cultural Monuments at the Ministry of Culture of the Republic of Croatia, therefore refurbishing from the inside is suggested.

The vapour barrier is integrated inside prior to fixing the mineral wool (MW: 8 cm and panelling) in order to prevent condensation. There are often prejudices against insulation from the inside because of the bad reputation of the systems that were used previously. Today technically sophisticated systems are available.

Inovations

New insulation materials are high valued thermal insulation of little thickness. They have small density (10-150 kg/m²) and low thermal conductivity (λ = 0,025-0,050 W/mK). Its values make them useful in situation where high insulation requirements or space constraints make traditional insulation impractical. Building work that requires a reduction in the thickness of insulation materials can easily be carried out using new insulating materials that are thinner than conventional but offer the same insulation performance (Figure 3).

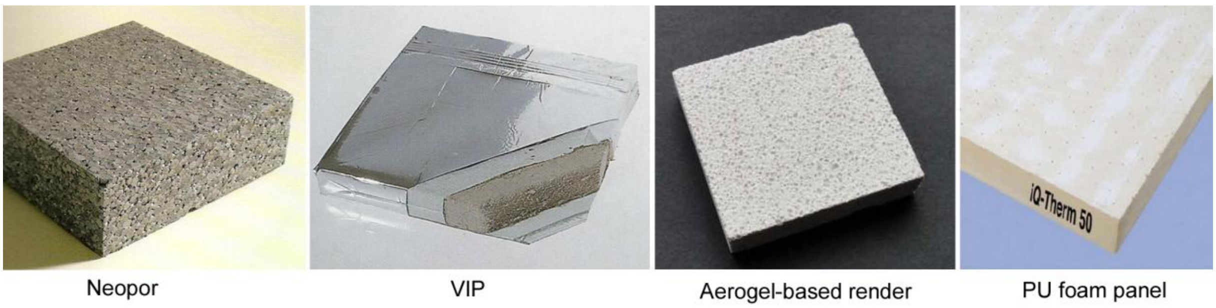

Figure 3. High valued thermal insulations: 1. Neopor, 2. Vacuum insulated pane (VIP), 3. A block of the aerogel-based render, 4. A breathable rigid polyurethane foam panel for internal wall insulation system.

Neopor. Neopor, an expandable polystyrene (EPS), is a new material for external thermal insulation composite systems (ETICS). Neopor foams are silvery grey in colour because they contain graphite, which considerably increases insulation performance. Neopor insulating materials with a bulk density of 15 kg/m³ achieve a thermal conductivity of 0,032 W/(mK). In normal EPS with the same bulk density, the thermal conductivity is 0,037 W/(mK) [3].

Vacuum insulated panel (VIP). Vacuum Insulated Panels, called VIP, are insulating structures that consist of almost gas-tight enclosure and a rigid core from which the air has been evacuated. By removing air from fiber, powder or foam core materials VIPs achieve high thermal performance. A VIP is an insulation product that is 5 to 10 times thinner than conventional insulation materials used in building with the same heat transfer coefficient (U-value). A thermal conductivity value is 0,005 W/mK. Higher cost generally keep them out of traditional housing situations. VIPs have been successfully implemented in buildings for several years. VIP products are made-to-fit architectural details, for floor, wall, and roof constructions [3].

Aerogel-based high performance insulating render. New high performance insulating render, which boasts a thermal insulation value 3-times, better than convention render thanks to aerogels. The new render is both optically and in application very similar to the original historical building materials thanks to its mineral basis. It is ideal for use on old buildings (on internal and external surfaces). Aerogel is a substance, which possesses nanometersized pores and consists of 90 to 09 per cent air. These pores make aerogels an excellent material for use in the new insulating render, lending it a thermal conductivity value of less than 30 mW/mK (2 to 3 times better than that of conventional render). The insulating render is sprayed onto walls. The first buildings will be rendered beginning in mid 2012 [4].

Breathable interior insulation system (iQ-Therm). The system is targeted for refurbishing buildings from the inside. It is remaining fully breathable (with no vapour barrier). This insulation consists of a breathable rigid polyurethane foam panel, adhered to the structure walls, rendered and painted. The installed system has an immense capacity to store and transport moisture, which buffers peak moisture loads in the air of the room, regulating the climate. Over the long term, buildings can dry out and make significant energy savings. Boards achieve medium value of thermal conductivity (λ = 0,065-0,1 W/mK) [5].

3. Improving Window Insulation

Wooden double windows (single-glazed) and outer sun protection (shutters) should be kept and repaired. Openings and proportions of the windows should adapt to the style in shape and detail. Overall heat transfer coefficient of windows should be less than 1,8 W/m^{2}K. This project suggests specific windows advanced with double glazed low E (3+8+3 mm) secondary glazing (U-value = 1,1 W/m^{2}K). Installing external applications or double-glazing on a listed building will need planning permission from the Municipal Institute for Protection of Cultural and Natural Monuments.

After windows repairs, along with step I. and II., the heat loss can be reduced by 5-12,50% by improving the window insulation. The annual thermal heat demand can be reduced from 4% to 9% in relation to current state.

RESULTS

This research looks at a range of improvements that can be made to reduce the heat lost through the building's walls, windows, floors and roofs. The thermal comfort inside the building could be crucially increased by additional insulation.

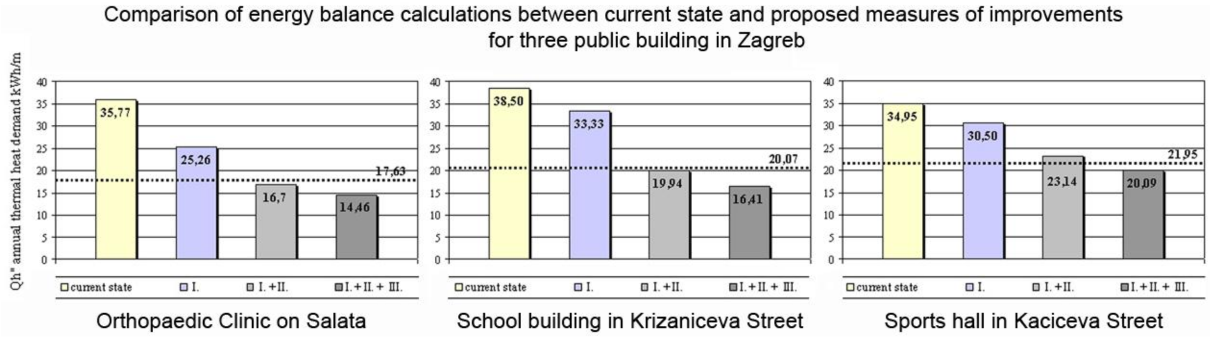

Figure 4. Comparison of energy balance calculations between current state and proposed measures of improvements for three public building in Zagreb

It is necessary to apply all three steps in the package of measures for energy-saving restoration (Figure 4). It is possible to limit the heat losses with solutions, which are technically simple to implement. The building can't meet the present-day technical regulation without applying the suggested measures of the preservation project.
The final research results of individual analysis and suggestion for renovation measures for three chosen public buildings are presented in following Table 2. These figures show the great energy-saving potential for the renovation of buildings from the construction period of 1930 to 1940.

Table 2. Comparison of thermal characteristic of building envelopes before and after the proposed measures

Results of energy balance calculations after the proposed measures								
AFTER THE PROPOSED MEASURES	allowed Ht' W/m^2K	steps of improvements Ht' - specific transmission heat loss W/m^2K			allowed Qh' kWh/m^3a	steps of improvements Qh' - annual thermal heat demand kWh/m^3a		
		I.	I.+II.	I.+II.+III		I.	I.+II.	I.+II.+III
Orthopaedic Clinic	0,85	1,02	0,62	0,45	17,63	25,26	16,70	14,46
School in Krizaniceva St	0,66	1,10	0,65	0,52	20,07	33,33	19,94	16,41
Sports hall in Kaciceva St	0,58	0,69	0,51	0,41	21,95	30,50	23,14	20,09

CONCLUSION

This research shows that with the appropriate renovation measures the energy requirement of existing public buildings can be brought up to today's standard for newly built houses. Differences in applying renovation measures result from the level of building conservation. If the renovation of listed building is in question, the renovation measures are aimed to retain the outer look but according to energetic and thermal needs. The buildings of the modern era and the renovation initiatives can serve as exemplary case studies for the widespread renovation efforts of existing buildings.

Today's technology and science development is producing materials with the most convenient characteristics, thickness and way of building in, which makes a great contribution in building construction and renovation. The possible decrease of efficient loss of housing space, while refurbishing buildings from the inside, is in installing high valued thermal insulation of less thickness or advanced sophisticated system of inner thermal insulation system on the basis of capillary damp transfer.
With optimal renovation planning project heat loss can be prevented, greater savings attained in heating energy consumption and old buildings can be usable again.

REFERENCES

1. Muraj, I., Modern Architecture in the Work of Egon Steinmann, *M.Sc. Thesis*, University of Zagreb, Faculty of Architecture, Zagreb, 2004
2. Muraj, I., Historical Buildings in Contemporary Usage. Analysis Based on Chosen Buildings of Egon Steinmann, *Ph.D. Thesis*, University of Zagreb, Faculty of Architecture, Zagreb, 2009
3. Kerschberger, A.; Brilinger, M.; Binder, M., *Energieeffizient Sanieren, Mit innovative Technik zum Niedrigenergiestandard*, Solarpraxis AG, Berlin, pp 47, 50-54, 2007
4. *Aerogel-based Render*, EMPA, Duebendorf, Switzerland, 2010 (www.empa.ch)
5. *Restoration Measures That Save Energy*, Remmers Limited Crawley, UK (www.remmers.co.uk)