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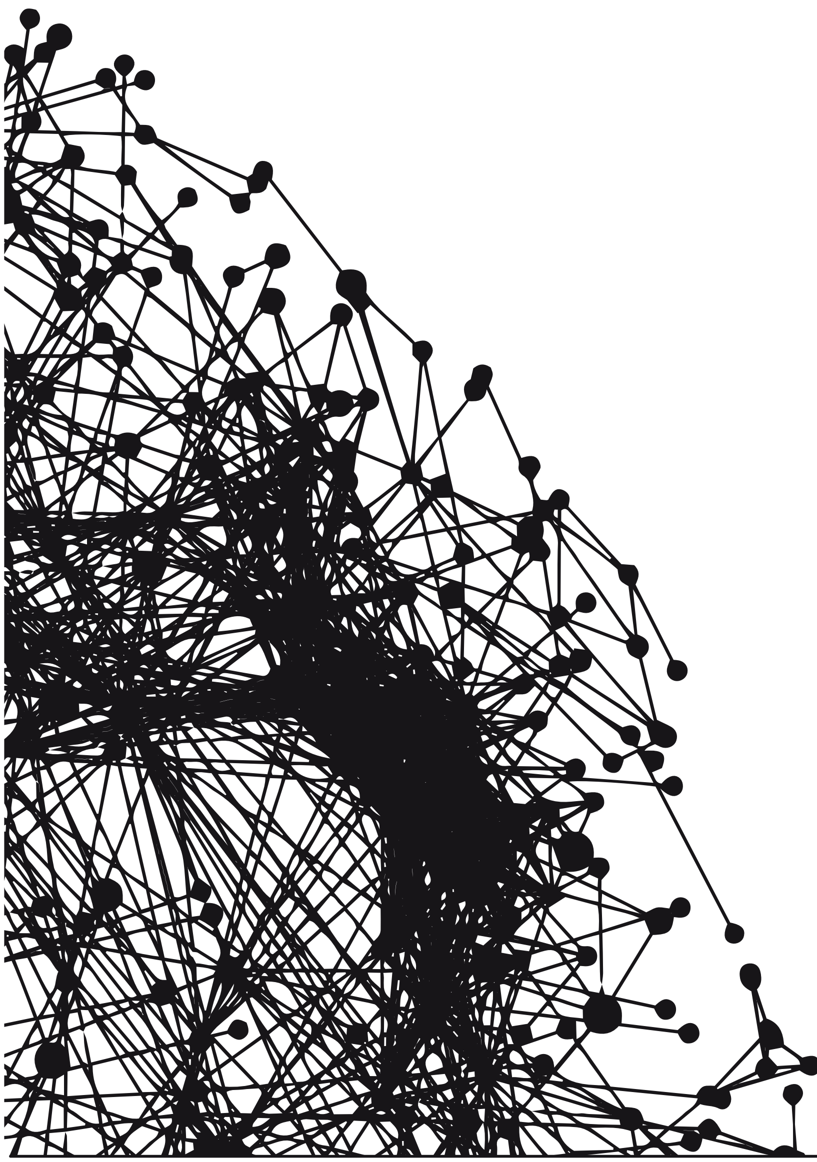

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ENERGY OPTIMIZATION OF THE BUILDING ENVELOPE OF THE REPRESENTATIVE SAMPLE OF THE EXISTING RESIDENTIAL BUILDING IN BANJA LUKA

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Abstract

The primary task of this paper is to present to the scientific and professional community the application of regulations in the field of energy efficiency of Serbia and Croatia, based on the specific example of a representative sample of the building envelope of the existing residential building, in the climatic conditions of the city of Banja Luka (Republic of Srpska, Bosnia and Herzegovina). It will be pointed out to the adequate settings of a limit for maximum U-values (limit for maximum thermal transmittance values) for the elements of the building envelope, in order to comply with specific heat transmission losses in relation to the factor of building form (A/V ratio) for residental buildings, in case of refurbishment of entire envelopes of existing residential buildings, as well as in case of building new ones. This paper presents the analysis of energy savings and costs of measures applied to the energy optimization of the building envelope on the representative sample of the existing residential building in Banja Luka.

***Keywords**: energy optimization, building envelope, energy efficiency measures*

Introduction

The energy consumption, which is constantly growing due to higher living standards, is leading to impoverishment of natural resources and environmental pollution, which indirectly affects the global climate change. Given the estimate that in the Republic of Srpska (Bosnia and Herzegovina) about 51.8% of the total energy is consumed in the building stock, one of the priorities as well as long-term goals is the research of energy optimization of buildings. The concept of energy optimization of buildings, which has requirements for minimum energy consumption, is affected by the overall boundary conditions (use, energy, climate and comfort), urban infrastructure and environment parameters, building envelope, building installation, materials and strategies, concepts and legislation as a basis for planned measures of buildings' renovation complying with energy, economic and environmental requirements [1]. This paper presents the analysis of energy savings and cost efficiency of measures applied to the energy optimization of the entire envelope of specified examples, and in the absence of objective regulations in Republic of Srpska, at the same time it provides adequate proposals for measurement settings for the climatic conditions of Banja Luka (maximum/limit of U-value [W/(m^2K)] - thermal transmittance for the elements of the building envelope).

Determination of the Representative Sample for Energy Optimization of Existing Residential Building

Examination of the existing building stock of a city of Banja Luka, achieved by analyzing the results of the census of population, dwellings and households conducted in the past (1961, 1971, 1981, 1991), following the adoption and implementation of regulations and standards for thermal protection of buildings in the subject area, analyzing types of structural systems and materialization of residential buildings with an accent on both thermal transmittance value of structural elements of building envelope and the presence of the buildings in subject area, leads to the conclusion that almost all existing buildings' funds of the city of Banja Luka until 1980 should be renewed. The fact that the European Union is practice to refurbish buildings older than 40 years, due to the duration of the elements incorporated into the building (design time horizon duration of the building is 60 years)[158], suggests that the buildings built until the 1980 is a priority for refurbishment [2,3]. A representative sample of an existing residential building is determined by a detailed energy audit - determining the specific energy consumption for heating using EN ISO 13790:2008 - Energy performance of buildings – Calculation of energy use for space heating and cooling, when the samples of the two characteristic periods (1945-1967, Figure 1 and 1967-1980, Figure 2) led to the conclusion that Sample 1 from period 1945-1967 basically has a higher specific energy consumption for heating (use/final energy consumption for heating) than Sample 2 (internal design temperature in the rooms of dwellings is 20°C) (Table 1).

[158] Although these parameters are specified in ISO 15686-1:2011 'Buildings and constructed assets - Service life planning- Part 1: General principles and framework', an example of insulating glass according to 'The Construction Materials Manual' (Hegger et al., 2006.) indicates that insulating glass has a durability of 50 years; the European standard EN 1279 states that duration of 25 years must be provided, while in a refurbishment of buildings in Germany, 'Refurbishment Manual-maintenance, conversions, extension' (Giebeler et al., 2009.), it was determined that this kind of glazing has a lifespan of 20 -35 years, which indicates that the renovation of buildings is necessary after 30 years (replacement or reconstruction of major elements, for example windows, roofing and other envelope elements)

Figure 1: Sample 1 – Layout of building and position in settlement Kocicev vijenac

Figure 2: Sample 2 – Layout of building and position in settlement Borik

Table 1: Comparative review of the specific energy consumption for heating and CO_2 emissions of representative samples of existing residential buildings of the city of Banja Luka

		SAMPLE 1		SAMPLE 2	
PERIOD		1945-1967 (1964)		1967-1980 (1974)	
DIMENSION (A)		10x42m (2025m^2)		13,65x106m (6315m^2)	
FLOORS (V)		P+4 (5670m^3)		P+4 (17682m^3)	
ORIENTATION		NW - SE		E - W	
U-value WALLS	W/m^{2}K	2.03		1.35	
U-value WINDOWS	W/m^{2}K	3.12		3.08	
U-value ROOF	W/m^{2}K	1.64		0.70	
U-value FLOOR	W/m^{2}K	1.02		1.04	
g-value		0.49		0.34	
A/V ratio		0.40		0.46	
proportion of windows	%	23.70		19.90	
		ACTUAL	DESIGN	ACTUAL	DESIGN
internal temperature	°C	18	**19.2**	22.3	**20**
FINAL (USE) ENERGY	kWh/m^{2}a	143.6	**164.4**	181.1	**157.7**
DELIVERED ENERGY	kWh/m^{2}a	273.5	313.1	222.4	193.7
PRIMARY ENERGY	kWh/m^{2}a	369	**423**	300	**261**
CO_2 EMISSIONS	kg/m^{2}a	90.3	**103.4**	73.3	**63.9**
CO_2 EMISSIONS	t/a (year)	182.8	209.3	463.4	403.6

The efficiency of the heating system in the present samples has created a difference between the two samples, so that the specific energy consumption in Sample 1 is 4.2% higher than in Sample 2 (1967-1980). Building heating consumption of delivered energy and therewith primary thermal energy and CO_2 emissions are affected by the distance of the settlement where representative samples are situated, from the central district heating plants, resulting that the Sample 1 has about 62% higher consumption of primary energy and CO_2 emissions than Sample 2.

Review of Regulations on Energy Efficiency and Thermal Protection of Buildings in Countries in the Region

The efforts of the Republic of Srpska to slowly engage in activities that have taken root in the European Union are shown in the Energy Development Strategy of the Republic of Srpska to the 2030th year, adopted in March 2012, and the draft Law on Energy Efficiency accepted by the Assembly of the Republic of Srpska in June 2013. Since the Republic of Srpska has just passed the Law on Energy Efficiency, but legislation has not passed, there has been examined the new regulations related to thermal protection, rational use of energy and energy certification of buildings in countries in the region of Bosnia and Herzegovina, as well as in Bosnia-Herzegovina, but those are not applicable in the territory of the Republic of Srpska. In *The Regulation of Technical Requirements for Thermal Protection and Rational Use of Energy*, which has been in force since 2010 in the Federation of Bosnia and Herzegovina [4], it is evident that climatic zones of Croatia have been taken over, from the similar regulation which has been in force since 2008 in Croatia [5], resulting that the former three climate zones of the former Yugoslavia are reduced to two. In these Regulations of the Federation of Bosnia and Herzegovina and Croatia, indicators of energy class and height values of the maximum limit annual energy use for heating are divided into only two categories (residential and non-residential) and depending on the design building temperature (18 and higher and higher than 12 but less than 18) and the form factor of the building. In contrast to aforesaid regulations, the regulations of the Republic of Serbia, the *Regulation on Energy Efficiency of Buildings,* dated August 2011 and the *Regulation on the Conditions, the Content and Manner of Certification of the Energy Performance of the Building*, dated July 2011 (Figure 3.), classify the height of the value of the energy grade according to the six categories (types) of non-residential buildings and two residential categories. The maximum permissible annual final energy needed for heating is listed for each category [6].

Uncertainties related to the parameter of the allowed annual energy used for heating in the policies of the Federation of Bosnia and Herzegovina and Croatia are due to unknown fact whether this is an requirement for primary or final energy required. In the example of Germany, the energy identity card (passport) states calculated primary and final energy use for heating, hot water, variety of consumers of electricity and measured final energy consumption in the building. (Figure 4.)

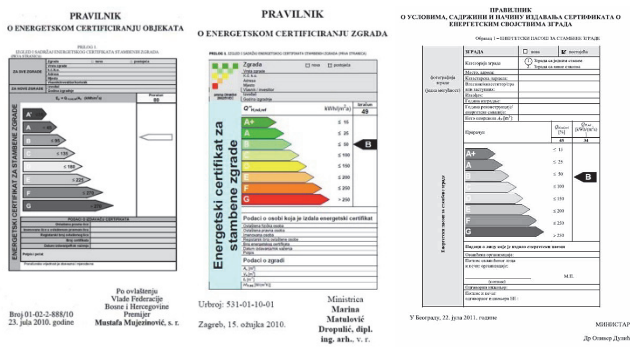

Figure 3. Review of Regulation on Energy Certification of Buildings in the Federation of Bosnia and Herzegovina (http://www.fmpu.gov.ba/pravilnici/pravilnik_energetsko_ certificiranje_objekata.PDF) and in Croatia (http://narodne-novine.nn.hr/clanci/sluzbeni/ 2012_07_81_ 1906.html) figure left and Regulations on Energy Certification of Buildings in Serbia (http://www.ingkomora.org.rs/strucniispiti/?stranica=materijalEE), figure right

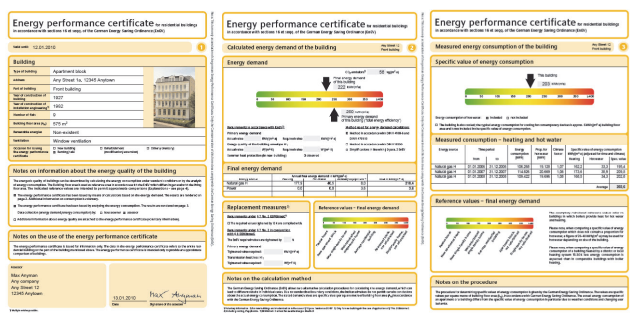

Figure 4. Example of the first three pages of the Energy Certificate for a Residential Building in Germany, retrieved on Oct 06, 2012 from http://www.zukunft-haus.info/index.php?id=9632

Values of energy classes (final specific energy consumption for heating), in Croatia and Serbia, are identical (e.g. class B≤50 , C≤100), whereas in the Federation of B&H are higher (e.g. class B≤95, C≤135). *The Regulation on Energy Efficiency in Buildings in Serbia* defines requirements to be fulfilled for renovating existing residential multi-storey buildings, as follow: to provide minimum comfort, to meet requirements for values not exceeding the threshold of limit value (maximum) of thermal transmittance for the elements of the building envelope of existing buildings, requirements for specific transmission heat loss depending on the building form factor, then the maximum permissible annual heating energy consumption of existing residential buildings does not exceed 70 kWh/m^{2}a and energy rating of the existing building after refurbishment must be improved by at least one class.

Technical Regulations on the Rational Use of Energy and Thermal Protection of Buildings in Croatia, which is identical to the one in the Federation of Bosnia and Herzegovina, defines the requirements to be fulfilled for the refurbishment of buildings in the following cases of characteristic samples: when at least 75% of the building envelope of the heated part of the building is renewed or when at least 25% of each section of the building envelope is renewed. The requirements applied are equal to the requirements for new buildings, as follows: requirements for annual heat energy for heating per m^2 depending on the form factor of the building, the requirement for the transmission heat losses depending on the building form factor and the threshold limit value (maximum) of thermal transmittance for the elements of the heated building envelope.

Roots related to above regulations can be seen in the German regulation on energy saving (EnEv), dated 2002, with one exception that under this regulation the building must comply with the initial requirements; residential buildings must fulfil the requirements for transmission heat loss depending on the form factor of the building. While in case of other building types, it depends on the area of the windows, requirements for transmission heat loss depending on the form factor of the building and/or the annual primary energy consumption of the building [7].

Analysis of Energy Saving by Applying Selected Refurbishment Measures in Order to Energy Optimization of Envelope of Relevant Representative Sample

The research was conducted using the criterion of certified physical and technical characteristics of materials from certain manufacturer, availability and prices of the material in Bosnia and Herzegovina. Those materials, due to the low thermal conductivity, are the most important component of measures for energy optimization of existing residential building envelope.

According to the *Regulation of Energy Efficiency in Serbia*, if we take into consideration the limit for maximum value of the coefficient of thermal transmittance, U max [W/(m^2K)] for the elements of the thermal envelope of the existing building, Sample 1 will reduce the specific design used/final energy consumption for heating from 164.4 kWh/m^2a to 35.8 kWh/m^2a, or would have a 78% lower energy consumption for heating. If energy efficiency measures were reduced to the parameters of limit maximum U-value, according to this Regulation, for an external wall, a roof above an unheated space and a floor above an unheated space of 0.40 W/m^2K and for windows of 1.50 W/m^2K, Sample 1 would switch from the existing energy class F into energy class C, for three classes higher. If we take into consideration the measures relevant to the observed limit U-values [W/(m^2K)] for building components (after the refurbishment), correspond to the values specified in *Technical Regulation of the Rational Use of Energy and Thermal Protection of Buildings in Croatia* (identical to the Regulation in the Federation of Bosnia and Herzegovina), for Sample 1 specific design energy consumption for heating will be reduced from 164.4 kWh/m^2a to 42.9 kWh/m^2a (about 74% lower energy consumption for heating). By reducing of the energy efficiency measures merely on the parameters of maximum U-value, in accordance with these Regulations, for an external wall 0.45 W/m^2K, a ceiling above an unheated space (roof) 0.30 W/m^2K, a floor above an unheated space 0.50 W/m^2K and for a windows

1.80 W/m^{2}K, Sample 1 will switch from the existing energy class E into high energy class B, for three classes up. According to the *Regulations on the Energy Certification of Buildings of the Federation of Bosnia and Herzegovina*, Sample 1 will switch from energy class D into energy class A.

Analyses available, most appropriate materials and measures (VAT included measures' prices), according to the requirements of the limit U-values of the building envelope, for the refurbishment of Sample 1, would save up to 13.8% of invested assets (14050 EUR) in Croatia compared to Serbia, although if these requirements were applied in Serbia, savings in specific energy consumption for heating would be 7.1 kWh/m^2 higher than in Croatia or ~ 20% higher (Figure 5.)

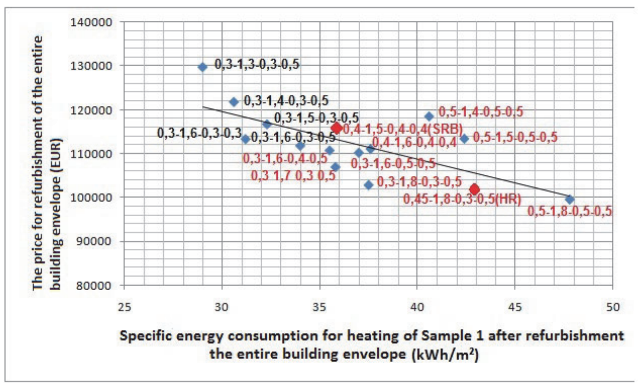

Figure 5. The relationship of specific energy consumption for heating Sample 1 and the price of works and materials for refurbishment (including VAT) in Bosnia and Herzegovina (prices from March 2013)

If we consider the specified parameters of transmission heat losses depending on the building form factor (achieving H'_T = 0.68 W/m^{2}K for A/V = 0.40 of Sample 1), the allowed values of the coefficient of thermal transmittance of an existing building do not fulfil the requirements for transmission heat losses in this Regulation (amount to 0.70 W/m^{2}K), although Umax [W/(m^{2}K)] in Sample 1 would reduce energy consumption for heating twice lower than limit (35,8 kWh/m^{2}a compared to 70 kWh/m^{2}a). It indicates that the Regulation in Serbia should clearly state what specific requirements should be fulfilled in the refurbishment of the existing (residential) buildings. According to Croatian regulations, by the introducing of requirements in the major reconstruction (more than 75 % tread) that must be attained, the annual energy consumption for heating per m^2 depending on the form factor of the building (for existing Sample 1 $Q'_{H,ND}$=61.6 kWh/m^2) and transmission heat losses depending on the building form factor (H'_T=0.675 W/m^{2}K), Sample 1 also cannot achieve the required transmission heat loss only by achieving limit (maximum) U-value (in Croatia achieving H'_T=0.81 W/m^{2}K, while according to rigorous U max [W/(m^{2}K)] of the Regulation in Serbia achieving H'_T=0.71 W/m^{2}K) - Figure 6.

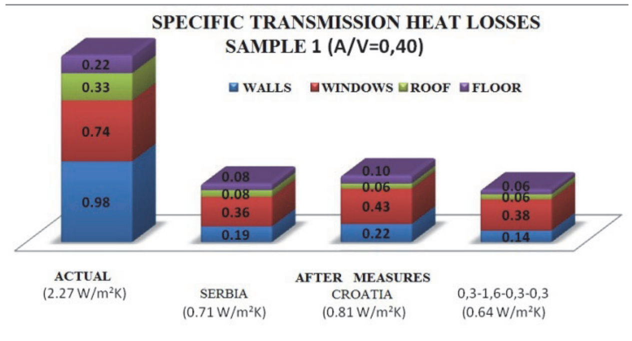

Figure 6. Comparative review of the current state of the specific existing transmission heat losses and the state after measures applied on the existing building envelope of Sample 1

Conclusions

The energy and economic analysis of the available measures for refurbishment of the residential building envelope, in Bosnia and Herzegovina, in the climatic conditions of the city of Banja Luka, determinates that the most prosperous setting of the limit U-values (coefficient of thermal transmittance) which would fulfil the requirements for transmission heat losses in relation to the form factor of the building of Sample 1, should be 0.30 W/(m^{2}K) for an external wall, 1.60 W/(m^{2}K) for an opening of the envelope (windows and doors), 0.30 W/(m^{2}K) for a ceiling under an unheated space (roof), and 0.30 W/(m^{2}K) for a ceiling above an unheated space (floor).

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