IZBOR OPTIMALANOG TIPA FASADNOG ZIDA KORIŠĆENJEM SOFTVERSKOG PAKETA „DESIGNBUILDER“

CHOOSING AN OPTIMAL TYPE OF FACADE WALL USING ‘’DESIGNBUILDER’’ SOFTWARE PACKAGE

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1 UVOD

Posmatrajući tržište materijala sa aspekta mogućih rešenja izrade fasadnih zidova dolazi se do zaključka da je iste moguće izvesti na mnogo načina. Izbor optimalnog tipa fasadnog zida sve više dobija na značaju s obzirom na stalni porast cena energenata i troškova izgradnje. Ukoliko tom izboru dodamo izbor odgovarajuće termoizolacione obloge, definisanje optimalne kombinacije postaje složenije. U okviru rada izvršena je analiza realnog objekta sa aspekta izbora optimalne kombinacije zida i termoizolacije.

Kako bi se izvršio izbor postavljen je kriterijum minimalnih ukupnih troškova. Troškovi analizirani u okviru rada odnose se na:

– troškove gubitaka toplotne nergije i

– troškove izgradnje fasadnih zidova sa završnom obradom.

Isti su analizirani za period eksploatacije objekta u trajanju od 30 godina.

U cilju što preciznije procene gubitaka toplotne energije kroz površine fasadnih zidova, analiza toplotnih karakteristika zidova izvršena je pomoću demo verzije

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1 INTRODUCTION

Observing the materials market from the aspect of possible solutions for realization of facade walls, a conclusion can be drawn that this can be done in numerous ways. The choice of an optimal type of facade wall is gaining in importance, regarding the continuous increase in prices of energy-generating products and building costs. If this choice involves the choice of proper thermal-insulation coating as well, the process of defining the optimal combinations gets more complex. This paper provides the analysis of an actual construction facility from the aspect of choosing the optimal combination of the wall and thermal insulation.

In order to make this choice, the condition of minimum total costs was set. The costs analyzed within this paper relate to:

– costs of thermal energy losses

– costs of realization of facade walls with finishing works.

These costs were analyzed for the period of 30 years, throughout which the construction facility is used.

With the aim of most accurate estimation of thermal energy losses through facade wall surfaces, the analysis

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programskog paketa DesignBuilder v2.0.5.013. u "Evaluation mode"-u [1].

2 ANALIZA FASADNIH ZIDOVA SA ASPEKTA TOPLOTNOG PRENOSA

Toplotni prenos ili U-vrednost je osnovni parametar usvojen za međusobno poređenje toplotnih karakteristika fasadnih zidova. Isti predstavlja količinu toplote, koja prođe kroz konstruktivnu sekciju, između unutrašnje i spoljašnje klime, za jedinicu površine i temperature. Jedinica mere je W/m²K. U-vrednost se u literaturi može naći i pod nazivom ukupni koeficijent prolaska toplote. Prema [2] izraz za U-vrednost je sledeći:

of thermal characteristics of walls was carried out by using a demo version of DesignBuilder v2.0.5.013 software package in "Evaluation mode" [1].

2 ANALYSIS OF FACADE WALLS FROM THE ASPECT OF THERMAL TRANSMISSION

Thermal transmission or U-value is the basic parameter adopted for comparison of thermal characteristics of facade walls. This parameter presents the amount of heat that passes through a construction section, between the inerior and exterior themperature condition, for a unit of surface and temperature. The unit of measurment is W/m²K. U-value is also called the overall heat transfer coefficient. According to [2], the formula for calculating the U-value is the following:

$$U = 1/R_T \; [W/m^2K]$$

gde je:

R_T – suma otpora prolaza toplote.

Vrednost U ocenjuje energetsku efikasnost materijala kombinovanih u jednoj konstruktivnoj komponenti ili sekciji. Što je vrednost parametra manja, rešenje je bolje u smislu toplotne izolacije i uštede energije. Ukupna toplotna otpornost i toplotni prenos se koriste u oceni i međusobnom poređenju građevinskih konstruktivnih rešenja. Takođe se koriste u različitim građevinskim normama širom sveta kako bi se uspostavili prihvatljivi standardi termičkih karakteristika kako novih tako i postojećih objekata. U tabeli 1 (prema [3]), prikazane su standardima postavljene maksimalne vrednosti toplotnog prenosa za pojedine države unutar i izvan Evropske unije.

where the following is:

R_T - thermal resistance.

U-value assesses the energy efficiency of materials combined in a single construction component or section. The lower the parameter, the better the solution in terms of thermal insulation and energy saving.Overall thermal resistance and thermal transmission are used when assessing and comparing construction solutions in civil engineering. They are also used in diferent building construction norms worldwide, in order to set acceptable standards for thermal characteritics of both new and existing construction facilities. Table 1 (compare [3]) shows standardized maximum values of thermal transmission for certain countries in and out of the European Union.

Tabela 1. Maksimalne dozvoljene vrednosti za U-vrednost u okviru pojedinih država
Table 1. Maximum allowed values for U-value in certain countries

Država (Country)	Grad (City)	U [W/m²K]		
		Zid (Wall)	Krov (Roof)	Tavanica (Ceiling)
Bosna i Hercegovina (Bosnia and Herzegowina)	Sarajevo	0.80	0.55	0.65
Bugarska (Bulgaria)	Sofia	0.50	0.30	0.50
Hrvatska (Croatia)	Zagreb	0.90	0.65	0.75
Francuska (France)	Paris	0.36	0.20	0.27
Mađarska (Hungary)	Budapest	0.45	0.25	0.50
Makedonija (Macedonia)	Skopje	0.90	0.65	0.75
Rumunija (Romania)	Bucharest	0.70	0.33	0.60
Slovenija (Slovenia)	Ljubljana	0.60	0.25	0.45
Srbija (Serbia)	Novi Sad	0.90	0.65	0.75

2.1 Analiza pojednih tipova fasadnih zidova

Izbor tipova fasadnih zidova usvojenih u okviru analize izvršen je na osnovu observacije tržišnih uslova. Ispitivanje tržišta sa aspekta varijantnih rešenja nije izvršeno samo u cilju određivanja tipova fasadnih zidova koji su trenutno u najširoj upotrebi u slučaju izgradnje novih objekata već su uzeta u obzir i rešenja koja su karakteristična za stare objekte pa i za objekte koji ne ispunjavaju standarde građenja. Analizirane su sledeće varijante tj. tipovi fasadnih zidova:

2.1 Analysis of certain types of facade walls

The choice facade wall types accepted within the analysis was made according to observation of market conditions. The market analysis from the aspect of variant solutions was not only carried out with the aim of determining what types of facade walls are most commonly used when building construction facilities. It also took into consideration solutions which are typical of older construction facilities as well as those that do not meet construction standards. The following variants, i.e. types of façade walls were analyzed:

1. „sendvič“ zid,
2. „Porotherm“ zid,
3. „YTONG“ zid,
4. zid od pune opeke d=25cm,
5. zid od pune opeke d=25cm sa ekspandiranim penopolistirolom (tzv. EPS),
6. zid od giter bloka d=25cm,
7. zid od giter bloka d=25cm sa EPS i
8. zid od giter bloka d=25cm sa EPS plus 8cm.

U okviru tabele 2 prikazani su svi slojevi svih osam analiziranih varijanti fasadnih zidova pri čemu su podaci o termičkim karakteristikama istih dobijeni iz literature različitih proizvođača materijala [4], [5], [6], [7].

1. ‘’sandwich’’ wall
2. ’’ Porotherm’’ wall
3. ‘’YTONG’’ wall
4. full brick wall (25cm thick)
5. full brick with expanded polystyrene foam (the so called EPS) wall (25cm thick)
6. hollow clay block wall (25cm thick)
7. hollow clay block with EPS wall (25cm thick) and
8. hollow clay block wall EPS plus 8cm wall (25cm thick).

Table 2 shows all layers of eight analyzed variants of facade walls, where the data on their thermal characteristics come from specifications of different material producers [4], [5], [6], [7].

Tabela 2. Prikaz slojeva analiziranih fasadnih zidova
Table 2. Overview of layers of the analyzed facade walls

Vrsta zida (Type of wall)	Sloj (Layer)	d [cm]		λ [W/mK]	U [W/m²K]
1. Sendvič zid (Sandwich wall)	Klinker opeka ošupljena (Klinker hollow brick)	12	43.5	0.790	**0.550**
	Ploče od prošivene trske (Woven cane panels)	5		0.046	
	Puna opeka 1600 (Full brick 1600)	25		0.640	
	GrundPutz Leicht	1.5		0.810	
2. Porotherm zid (Porotherm wall)	EdelPutz	0.3	44.5	0.810	**0.296**
	UniversalGrund	0.3		0.810	
	PutzSpachtel	0.4		0.810	
	ThermoExtra	4		0.090	
	Porotherm 38 S P+E PLUS	38		0.139	
	GrundPutz Leicht	1.5		0.810	
3. YTONG zid (YTONG wall)	SilikatPutz	0.2	37.5	0.700	**0.235**
	UniversalGrund	0.3		0.810	
	HaftMörtel	0.5		0.810	
	Glasswool FDP 2	5		0.035	
	YTONG TZB 30	30		0.114	
	GrundPutz Leicht	1.5		0.810	
4. Puna opeka bez termoizolacije (Full brick without thermal insulation)	Produžni krečni malter (Lime mortar render)	2	29	0.870	**1.649**
	Puna opeka 1600 (Full brick 1600)	25		0.640	
	Produžni krečni malter (Lime mortar render)	2		0.870	
5. Puna opeka + EPS (Full brick + EPS)	EdelPutz Special	0.2	32.5	0.700	**0.525**
	KlebeSpachtel	0.3		0.810	
	EPS AF	5		0.038	
	Puna opeka 1600 (Full brick 1600)	25		0.640	
	Produžni krečni malter (Lime mortar render)	2		0.870	
6. Giter blok bez termoizolacije (Hollow clay block without thermal insulation)	Produžni krečni malter (Lime mortar render)	2	29	0.640	**1.167**
	Giter blok	25		0.390	
	Produžni krečni malter (Lime mortar render)	2		0.640	
7. Giter blok + EPS (Hollow clay block + EPS)	EdelPutz Special	0.2	32.5	0.700	**0.464**
	KlebeSpachtel	0.3		0.810	
	EPS AF	5		0.038	
	Giter blok	25		0.390	
	Produžni krečni malter (Lime mortar render)	2		0.640	
8. Giter blok + EPS Plus (Hollow clay block + EPS Plus)	EdelPutz Special	0.2	35.5	0.700	**0.299**
	KlebeSpachtel	0.3		0.810	
	EPS AF Plus	8		0.032	
	Giter blok	25		0.390	
	Produžni krečni malter (Lime mortar render)	2		0.640	

3 POSTUPAK ANALIZE

Proces utvrđivanja optimalne varijante fasadnog zida izvršen je kroz sledeće aktivnosti:

– analiza posmatranog objekta za čije potrebe izgradnje je neophodno utvrditi optimalno rešenje,

– precizna procena gubitaka toplotne energije i troškova nastalih usled istih za posmatrani objekat i

– analiza i utvrđivanje troškova izgradnje posmatranih varijanti fasadnih zidova.

3.1 Opis analiziranog objekta

Za prikaz predložene analize usvojen je objekat koji se nalazi u Novom Sadu i spratnosti je Po+P+1+M+Potk dok su gabariti objekta 21.00 x 14.39 + 9,87 x 8.90 m. U pogledu namene, objekat je stambeno-poslovan. Na spratovima, mansardi i potkrovlju smešteni su isključivo stanovi. Podrum je predviđen samo ispod dvorišnog dela objekta i sadrži stanarske ostave i toplotnu podstanicu.

Stanovi su u funkcionalnom smislu tako koncipirani da su prostorije za dnevni boravak predviđene na zapadnoj strani dok su prostorije za odmor i spavanje sa kupatilom predviđene na istočnoj strani.

Predviđeni konstruktivni sistem za analizirani objekta jeste masivni sistem sa međuspratnom konstrukcijom tipa „Fert“. Zidani elementi ukrućeni su AB serklažima u skladu sa važećim pravilnikom za zidane konstrukcije. Planirani krovni pokrivač je falcovani crep.

S obzirom da je cilj analize izbor optimalne kombinacije slojeva fasadnog zida, izvršene su određene korekcije analiziranog objekta kako bi se ubrzao rad u navedenom softveru. Kako analizirane kombinacije fasadnih zidova ne postoje u suterenu isti nije razmatran u analizi. Takođe, na zapadnoj i istočnoj strani drugog sprata objekta mansarda je zamenjena fasadnim zidom kako bi se povećale analizirane površine. Svi ostali podaci i detalji su uneti i modelovani identično ili najpribližnije moguće u skladu sa projektnom dokumentacijom.

Stambena površina objekta iznosi 836.96 m^2, dok je vrednost zapremine 2642.64m^3. Površina fasada objekta je 814.38 m^2 dok površina svih otvora zajedno iznosi 152.78 m^2. S obzirom na prethodno izneto u ukupna površina fasadnih zidova objekta iznosi 661.60 m^2.

Prikaz objekta u okviru prozora za modelovanje korišćenog softvera dat je na slici 1.

Tokom eksploatacije zagrevanje objekta vršiće se putem gasa. U suterenu je predviđena izgradnja podstanice koja će sem zagrevanja prostorija služiti i za zagrevanje vode.

3 THE ANALYSIS PROCESS

The process of determining the optimal type of facade wall was completed through the following activities:

– analysis of the observed construction facility whose building requires an optimal solution

– precise estimation of thermal energy losses and their consequential losses

– analysis and identification of construction costs for the observed types of facade walls.

3.1 Description of the analyzed construction facility

Suggested analysis comprised a construction faclility located in Novi Sad,with the following number of floors: Basement + Groundfloor + 1st floor + garret + loft. The gabarit of the facility is 21.00 x 14.39 + 9,87 x 8.90m. Regarding its purpose, it is a business – residential facility. Floors, garret and loft only contain flats. The basement is planned only under the yard of the facility, and contains residents' storage rooms and heat substatin.

In the functional sense, the flats are planned in the way that living rooms face west, whereas the relaxation rooms and bedrooms with bathrooms face east.

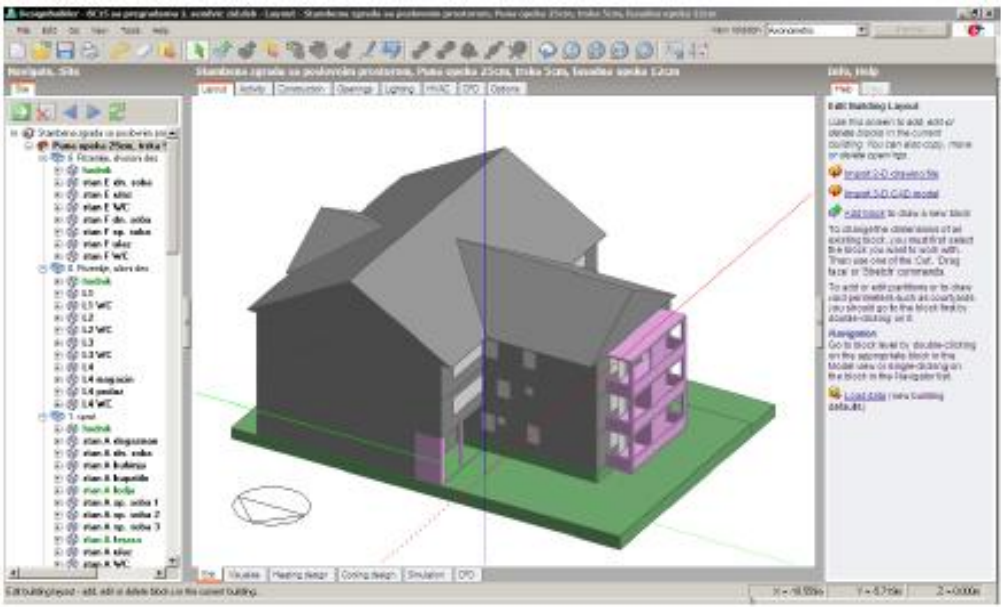
The planned construction system for the analyzed facility is the massive system with interfloor construction of ''Fert'' type. Masonry elements are reinforced with AB wall corners, according to the official regulations on masonry constructions. The planned roof covering is Roman roof tile.

Since the aim of the analysis is the choice of the optimal combination of facade wall layers, certain corrections of the analized construction facility were done, in order to perform work in the mentioned software faster. Considering the fact that there are no facade walls in the basement, it was not included in the analysis. In addition, on the east and west side on the 2nd floor of the facility, the garret was substituted by a facade wall, in order to increase the area of the analized surface. The rest of the data and details were entered and modeled identically or as close as possible according to the project documentation.

Residential area of the construction facility amounts to 836.96m^2, whereas the value of its volume amounts to 2642.64m^3. The facade area is 814.38m^2, and the total area of all doors and windows is 152.78m^2. According to this, the total area of facade walls amounts to 661.60m^2.

The overview of the construction facility in the modeling window of the used software is given in picture 1.

While it is being used, the facility will have gas heating. A substation is planned to be built in the basement. Apart from heating the rooms, it will also be used to heat water.



Slika 1. Prikaz analiziranog objekta u okviru prozora za modelovanje softvera DesignBuilder
Figure 1. Overview of the enalyzed facility in the modeling window of Design Builder software

3.2 Proračun toplotnih gubitaka i troškova istih

U okviru korišćenog softverskog paketa analizirani su utrošci električne energije i gasa pri čemu su u okviru analize gubitaka gasa usvojeni isključivo gubici nastali kroz fasadne zidove s obzirom da je moguće izdvojiti gubitke nastale kroz različite fasadne elemente.

Kako softver pruža mogućnost detaljne analize svih definisanih tipova energenata, npr. gasa i električne energije, u zavisnosti od izvora gubitaka, tokom analize je bilo neophodno utvrditi gubitke toplotne energije nastale isključivo kroz površine fasadnih zidova.

S druge strane, u cilju utvrđivanja finansijskih troškova nastalih usled gubitaka toplotne energije, gubici iste u okviru softvera povezani su sa količinama gubitaka gasa kao energenta.

Nakon definisanja karakteristika varijantnih rešenja usvojene su vrednosti troškova energenata. Prilikom analize troškova gubitaka toplotne energije usvojeno je da je cena $1m^3$ gasa iznosi 0,40€. S obzirom da su gubici energije u okviru rada prikazani u kWh potrebno je napomenuti da $1m^3$ gasa obezbeđuje 9,5kWh energije.

Utvrđene vrednosti gubitaka toplotne energije za različite tipove analiziranih varijanti fasadnih zidova prikazane su u okviru tabele 3. Slika 2, s druge strane, prikazuje količine izgubljenog gasa. Prikazani gubici za period od godinu dana odnose se samo na gubitke toplotne energije kroz površine fasadnih zidova bez uzimanja u obzir veličine infiltracije koja takođe, svojim manjim delom, zavisi od vrsta slojeva fasadnog zida.

3.2 Calculation of thermal losses and their costs

Within the used software package, the consumption of electricity and gas were analized, where the analysis of gas losses only considered those occuring through facade walls, since it is possible to identify losses occuring through different facade elements.

Since the software provides the possibility of detailed analysis of all defined types of energy-generating products, such as gas and electricity, depending on the source of loss, it was necesary to determine thermal energy losses ocurring only through facade wall surfaces.

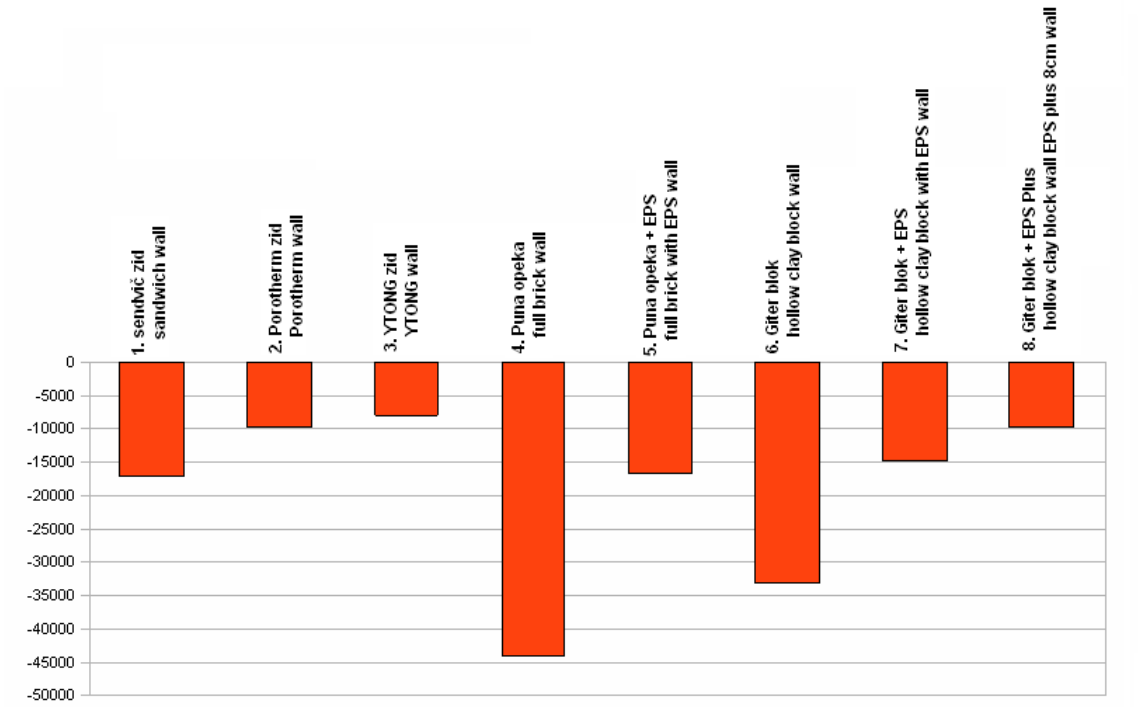
On the other hand, with the aim of determining financial expenses resulting from thermal energy losses, these losses were linked with the quantity of gas losses within the software.

Having defined the characteristics of variant solutions, the values of energy-generating products were adopted. While analyzing the expenses of thermal energy losses, it was agreed that the price of $1m^3$ of gas amounts to 0.40 €. Since the energy losses within the paper are expressed in kWh, it must be noted that 1 m^3 of gas provides 9.5 kWh of energy.

Determined values of thermal energy losses for various types of analyzed variants of facade walls are shown in table 3. Picture 2, on the other hand, shows amounts of lost gas. Presented losses for the period of one year only relate to losses of thermal energy through surfaces of facade walls, regardless of the amount of filtration which also, in its smaller segment, depends on the type of facade wall.

Tabela 3. Gubici toplotne energije kroz površine fasadnih zidova
Table 3. Losses of thermal energy through surfaces of facade walls

	Vrsta zida (Type of wall)	w[cm]	U[W/m^{2}K]	Gubici zida za 1 godinu (Losses during 1 year)	
				[kWh]	[€]
1.	(Sendvič zid) Sandwich wall	43,5	0,550	-17.075,83	718,98
2.	Porotherm	44,5	0,296	-9.791,61	412,28
3.	YTONG	37,5	0,235	-7.927,68	333,80
4.	Puna opeka (Full brick)	29,0	1,649	-43.884,70	1.847,78
5.	Puna opeka + EPS (Full brick + EPS)	32,5	0,525	-16.537.62	696,32
6.	Giter blok (Hollow clay block)	29,0	1,167	-33.029,64	1.390,72
7.	Giter blok + EPS (Hollow clay block + EPS)	32,5	0,464	-14.777,61	622,22
8.	Giter blok + EPS Plus 8cm Hollow clay block + EPS Plus 8cm	35,5	0,299	-9.858,74	415,10



Slika 2. Uporedni dijagram gubitaka gasa prema tipu fasadnog zida
Figure 2. Comparative diagram of gas losses according to facade wal typel

3.3 Proračun troškova izgradnje fasadnih zidova

Troškovi izgradnje fasadnih zidova određeni su na osnovu tržišne vrednosti materijala i radne snage uz napomenu da su u cenu zida uračunati svi slojevi predstavljeni u tabeli 2.

Prikaz postupka određivanja troškova izrade fasadnog zida biće prikazan kroz primer „Porotherm“ fasadnog zida (varijanta 2).

3.3 Calculation of facade walls construction

Costs of facade walls construction are determined according to the market value of materials and labour force, keeping in mind that the price comprises all the layers presented in table 2.

The process of determining the costs of facade wall construction will be exemplified by ''Porotherm'' facade wall (variant 2).

U okviru tabele 4 prikazani su troškovi izrade zida od „Porotherm“ blokova dimenzija 38x25x23,8cm pri čemu je izrada spojnica izvršena uz upotrebu termo-maltera.

Table 4 shows the costs of constructing the wall made of 38x25x23,8cm ''Porotherm'' blocks, with the joints made by using thermo-mortar.

Tabela 4. Troškovi radne snage i materijala za 1m^3 zida tipa Porotherm
Table 4. Costs of labour force and material for 1m^3 of Porotherm type wall

Opis operacije (Description of action)	**Grupa radnika (Group of workers)**	**NČ (Nh)**	**Blok (Block) [num]**	**Malter (Mortar) [m^3]**
Zidanje (Building)	PK (PQ)	0,800	42	0,18
	KV (Q)	2,100		
Prenos blokova (Transport of blocks)	NK (LQ)	0.531		
Prenos maltera (Transport of mortar)	NK (LQ)	0.168		
Spravljanje maltera (Mixing mortar)	NK (LQ)	0.864		
Cena (Price) [€]		7,28	45,00	65,10

Kako cene materijala i radne snage nemaju isto učešće u ukupnoj ceni, ista se formira prema sledećem izrazu [8]:

Since the costs of material and labour force do not participate equally in the total price, it is then formed according to the following formula [8]:

$$C = M + R(K+1)$$

gde je:
C – ukupna cena za 1m^3 gotovog zida
M – cena materijala za 1m^3 gotovog zida
R – cena radne snage za 1m^3 gotovog zida
K – koeficijent režije i dobiti (usvojeno K=3)
S obzirom na prethodno ukupna cena 1m^3 zida iznosi:

where the following are:
C – total price for 1m^3 of finished wall
M – the price of material for 1m^3 of finished wall
R – the price of labour force 1m^3 of finished wall
K – coefficient of overhead and profit (agreed K=3)
Considering all this, the total price of 1m^3 of wall amounts to:

$$C = 110,10 + 7,28(3+1) = 139,20€$$

Na isti način određuju se cena mašinskog malterisanja zida sa unutrašnje strane (tabela 5).

In the same way, it is possible to determine the price of machine plastering from the inside (Table 5).

Tabela 5. Troškovi radne snage i materijala za 1m^2 mašinskog malterisanja
Table 5. Costs of labour force and material for 1m^2 of machine plastering

Opis operacije (Description of action)	**Grupa radnika (Group of workers)**	**NČ (Nh)**	**Malter Mortar [kg]**
Malterisanje (Plastering)	Q	0,60	18
Prenos maltera (Transport of mortar)	LQ	0,04	
Cena (Price) [€]		1,25	4,14
Ukupna cena (Total price) [€]		9,13	

Struktura cene postavljanja termiozolacije i izrade završnih fasadnih slojeva prema uputstvima proizvođača „Baumit“ prikazana je u okviru tabele 6.

S obzirom da je za potrebe analize neophodno odrediti cene fasadnih zidova po 1m^2, cena izrade „Porotherm“ zida dobijena za 1m^3, iznosi 52,90 € za 1m^2 istog. Sledi da ukupna cena fasadnog zida tipa „Porotherm“ iznosi:

The structure of installation of thermal insulation and realization of final facade layer according to the instructions of the producer '' Baumit'' is given in table 6.

Since it is required by the analysis to determine the price of facade walls per 1m^2 , the price of construction of ''Porotherm'' wall calculated per 1m^3 amounts to 52.90 € per 1m^2 of the same wall. Hence, the total price of the facade wall of ''Porotherm'' type is:

$52,90 + 9,13 + 33,05 = 95,07$ €/m^2

Tabela 6. Troškovi radne snage i materijala za 1m^2 „Baumit“ termo-fasade
Table 6. Costs of labour force and material for 1m^2 of „Baumit“ thermo-facade

Opis operacije (Description of action)	Materijal Material [€]	Rad Labour [€]
Mašinsko nanošenje Baumit ThermoExtra maltera (Machine application of Baumit ThermoExtra mortar)	16,06	4,24
Izrada Baumit EdelPutz fasade (Realization of Baumit EdelPutz façade)		
Ukupna cena (Total price)	33,05	

U skladu sa prethodno iznetim postupkom određivanja cena definisani su troškovi za sve analizirane varijante fasadnih zidova i isti su prikazani u okviru tabele 7. Prikazani ukupni troškovi u tabeli 7 predstavljaju ujedno i inicijalne troškove za posmatrani period od 30 godina.

According to the previously presented method of determining the price, the costs of all analyzed variants of facade walls were defined and shown in table 7. Total costs given in Table 7 at the same time present initial costs for the observed period of 30 years.

Tabela 7. Troškovi izrade fasadnih zidova
Table 7. Costs of facade walls construction

Vrsta zida (Type of wall)	W [cm]	U [W/m²K]	Cena (Price) [€/m²]			Ukupna cena fasadnih zidova za ceo objekat (Total cost of facade walls for the whole facility)
			Materijal (Materia)	*Rad (Labour)*	*Ukupno (Total)*	
1. (Sendvič zid) Sandwich wall	43,5	**0,550**	€ 35,11	€ 50,70	***€ 85,81***	**€ 56.772,46**
2. Porotherm	44,5	**0,296**	€ 62,05	€ 33,03	***€ 95,07***	**€ 62.901,55**
3. YTONG	37,5	**0,235**	€ 35,40	€ 28,86	***€64,26***	**€ 42.517,24**
4. Puna opeka (Full brick)	29,0	**1,649**	€ 19,29	€ 35,82	***€ 55,11***	**€ 36.463,02**
5. Puna opeka + EPS (Full brick + EPS)	32,5	**0,525**	€ 25,67	€ 42,78	***€ 68,45***	**€ 45.284,96**
6. Giter blok (Hollow clay block)	29,0	**1,167**	€ 18,33	€ 31,68	***€ 50,01***	**€ 33.086,98**
7. Giter blok + EPS (Hollow clay block + EPS)	32,5	**0,464**	€ 24,71	€ 38,64	***€ 63,34***	**€ 41.908,93**
8. Giter blok + EPS Plus 8cm Hollow clay block + EPS Plus 8cm	35,5	**0,299**	€ 27,07	€ 38,64	***€65,70***	**€ 43.470,32**

4 ANALIZA DOBIJENIH REZULTATA

S obzirom da su definisani inicijalni troškovi, tj. ukupni troškovi izrade zidova kao i troškovi nastali usled gubitaka toplotne energije za period od godinu dana obezbeđeni su uslovi za poređenje varijantnnih rešenja.

Poređenje inicijalnih troškova izgradnje zidova, prikazanih u okviru tabele 8, uz dodavanje troškova nastalih usled gubitaka toplotne energije kroz vreme, u periodu od 30 godina, prikazano je u okviru tabele 8.

4 RESULT ANALYSIS

Having defined initial costs, i.e. total costs of wall construction as well as expenses resulting from thermal energy losses for the period of one year, the conditions for comparison of variant solutions were satisfied.

Comparison of initial costs of walls construction, shown in table 8, with the addition of expenses caused by the loss of thermal energy over time, during the period of 30 years, is shown in table 8.

Tabela 8. Promena troškova u periodu od 30 godina
Table 8. Change of costs during the period of 30 years

Vrsta zida (Type of wall)	Ukupna cena fasadnih zidova za ceo objekat (Total price of facade walls for the whole facility)	Porast troškova usled gubitaka toplotne energije za posmatrani period [god] (Costs increase due to thermal energy losse for the observed period [years])						
		1	3	5	10	15	20	30
Sendvič zid (Sandwich wall)	€ 56,772.46	€ 57,491.44	€ 58,929.41	€ 60,367.37	€ 63,962.28	€ 67,557.19	€ 71,152.10	€ 78,341.93
Porotherm zid (Porotherm wall)	€ 62,901.55	€ 63,313.82	€ 64,138.38	€ 64,962.94	€ 67,024.33	€ 69,085.72	€ 71,147.12	€ 75,269.90
YTONG zid (YTONG wall)	€ 42,517.24	€ 42,851.03	€ 43,518.63	€ 44,186.22	€ 45,855.21	€ 47,524.19	€ 49,193.18	€ 52,531.15
Puna opeka (Full brick)	€ 36,463.02	€ 38,310.80	€ 42,006.35	€ 45,701.90	€ 54,940.79	€ 64,179.67	€ 73,418.56	€ 91,896.32
Puna opeka + EPS (Full brick + EPS)	€ 45,284.96	€ 45,981.28	€ 47,373.92	€ 48,766.57	€ 52,248.17	€ 55,729.77	€ 59,211.38	€ 66,174.59
Giter blok (Hollow clay block)	€ 33,086.98	€ 34,477.71	€ 37,259.15	€ 40,040.59	€ 46,994.20	€ 53,947.81	€ 60,901.42	€ 74,808.64
Giter blok + EPS (Hollow clay block + EPS)	€ 41,908.93	€ 42,531.14	€ 43,775.57	€ 45,020.00	€ 48,131.08	€ 51,242.15	€ 54,353.23	€ 60,575.38
Giter blok + EPS Plus (Hollow clay block + EPS Plus)	€ 43,470.32	€ 43,885.42	€ 44,715.63	€ 45,545.84	€ 47,621.36	€ 49,696.89	€ 51,772.41	€ 55,923.46

Na osnovu prikazane tabele lako je uočiti isplativost pojedinih rešenja. U okviru analize porasta troškova nije analiziran kvalitet ponuđenih rešenja tj. troškovi eventualnog održavanja prikazanih tipova fasadnih zidova. Kako bi se lakše sagledali odnosi kao i dinamika promene troškova, formiran je uporedni dijagram prikazan na slici 3.

Sa dijagrama je lako uočljivo da se kao optimalno rešenje nameće varijanta pod rednim brojem 3, kombinacija zida „YTONG“ i termoizolacije od mineralne vune debljine 5cm, koja postaje najisplativija varijanta već posle 9 godina eksploatacije.

Poredeći dve najisplativije varijante, varijantu 3 i varijantu 8, moguće je uočiti da je razlika u porastu troškova mala i na kraju posmatranog perioda iznosi svega 6%.

Takođe, potrebno je sagledati odnose troškova „sendvič“ zida i zida od pune opeke bez termo-izolacije. Rešenje sa „sendvič“ zidom postaje isplativo posle 18 godina u odnosu na varijantu 4 što je posledica velikih troškova izrade sloja od fasadne opeke usled visoke cene fasadne opeke i visoke cene manualnog rada.

Ukoliko posmatramo odnos varijante 5 i varijante 7, koje su danas među najzastupljenijim na našem tržištu, dolazi se do zaključka da je opcija giter bloka i termo-izolacije tipa EPS debljine 5cm isplativija ali se odnos troškova gubitaka toplotne energije kroz vreme neznatno menja što sugeriše na veoma male razlike u termičkim karakteristikama.

Varijanta 4 (zid od pune opeke, d=25cm) analizirana je, iako ne ispunjava važeće propise, iz razloga velikog broja objekata koji nisu dovršeni a suprotno propisima su u upotrebi. Iz prikazanih slika 2 i 3 mogu se sagledati potencijalne razmere finansijskih gubitaka i gubitaka energije na nivou države.

According to the given table, the cost- effectiveness of certain solutions is easily noticable. The analysis of costs increase did not include the analysis of quality of suggested solutions, i.e. the costs of possible maintenance of presented types of facade walls. In order to easily percieve the relations as well as dynamics of costs changes, a comparative diagram shown in picture 3 was formed.

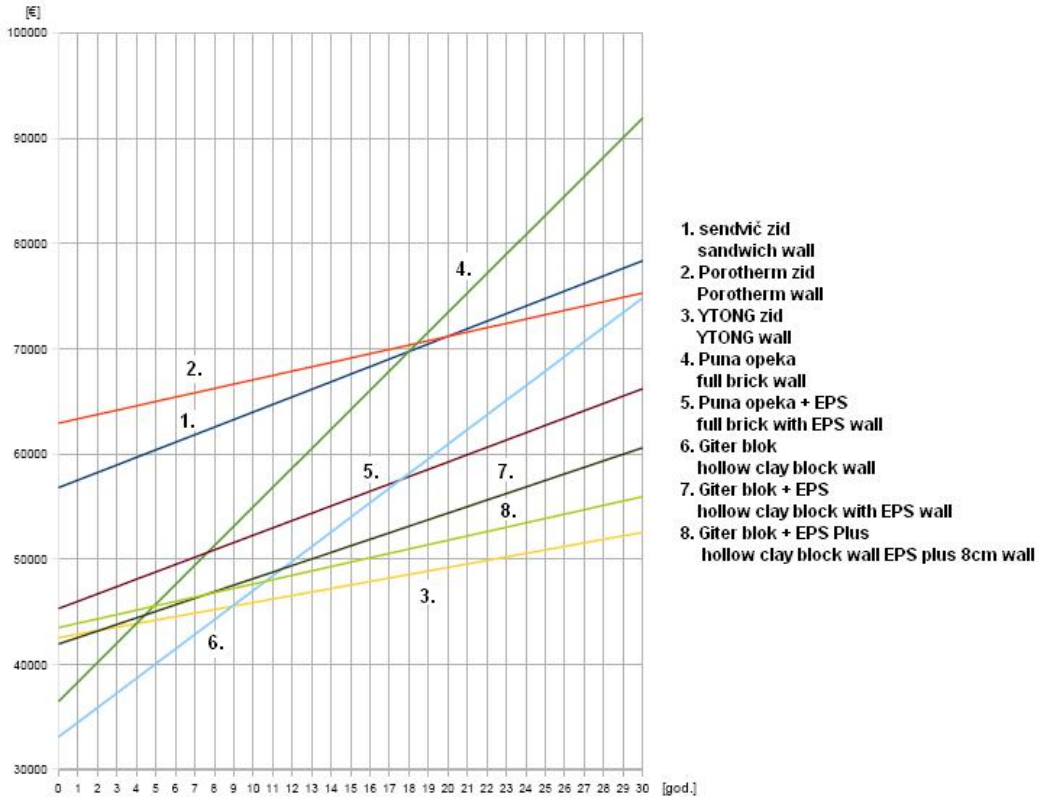
Based on the diagram, it can easily be seen that type number 3 imposes as the optimal solution. The combination of ''YTONG'' wall type and thermo-insulation of 5cm mineral wool, becomes cost – effective only after 9 years of exploitation.

Comparing two most cost –effective types, type 3 and type 8, it is possible to notice that the difference in costs increase is very small, reaching only 6% at the end of the observed period.

Furthermore, it is necessary to consider the relation between costs of ''sandwich'' wall and the wall made of full brick without thermal insulation. The solution with ''sandwich'' wall becomes cost – effective after 18 years, compared to type 4, which is a consequence of high costs of realization of a facade brick layer, due to high prices of facade bricks and costs of manual work.

If we consider the relation between type 5 and type 7, which are among the most frequent ones on our market, a conclusion can be drawn that the option of hollow clay block and thermal insulation of EPS type of 5cm is cost- effective, but the proportion of thermal energy losses over time changes insignificantly, which suggests very small differences in thermal characteristics.

Type 4 (full brick wall, W = 25cm) is analyzed, although it does not comply with official regulations, for



Slika 3. Uporedni dijagram troškova izgradnje i eksploatacije fasadnih zidova kroz vreme
Figure 3. Comparative diagram of the costs of construction and exploitation of facade walls over time

Ukoliko posmatramo isplativost postavljanja termoizolacije tipa EPS debljine 5cm u odnosu na neizolovan ali omalterisan zid od opeke, d=25cm, rešenje sa izolacijom postaje isplativo nakon nešto više od 7,5 godina.

Ukoliko uporedimo troškove fasadnog zida od giter bloka bez termoizolacije i sa termoizolacijom, varijanta sa EPS izolacijom debljine 5cm postaje isplativa za 11,5 godina dok opcija sa 8cm izolacije postaje isplativa za 10,5 godina.

5 ZAKLJUČAK

Primenom programskog paketa DesignBuilder v2.0.5.013. omogućena je potpuna analiza objekata sa aspekta energetske efikasnosti. Na taj način pružena je mogućnost za variranje i ocenu različitih tehničkih rešenja u procesu izrade projektne dokumentacije koja imaju uticaj na termičke karakteristike objekta.

U okviru rada prikazana je analiza različitih tipova fasadnih zidova, dostupnih na tržištu, sa aspekta troškova izrade i troškova nastalih usled gubitaka toplotne energije.

the reason of a large number of unfinished facilities which are being used, despite the existing regulations. From pictures 2 and 3, potential proportion of financial and energy losses at the national level can be estimated.

If we regard cost efficiency of thermal insulation of EPS type of 5cm compared to a non-insulated, but plastered full brick wall of 25cm, the solution with thermal insulation becomes cost -effective shortly after 7.5 years.

If the costs of hollow clay block wall with and without thermal insulation are compared, the option with EPS insulation of 5cm becomes cost- effective in 11.5 years, whereas the option with 8mm insulation becomes cost – effective in 10.5 years.

5 CONCLUSION

By applying Design Builder v2.0.5.013. software package, it is possible to carry out complete analysis of construction facilities from the aspect of energy efficiency. In this way, the possibility to alter and asses various technical solutions which influence thermal characteristics of facilities was prolonged during the process of making project documentation.

This paper provides the analysis of various types of facade walls, available on the market, from the aspect of frealization costs, as well as expenses resulting from thermal energy losses.

Zaključak je da se primenom novijih tipova termoizolacija i proizvoda namenjenih za izradu zidova, gubici višestruko umanjuju. Takođe pojedina rešenja, u odnosu na neizolovane fasadne zidove, postaju isplativa za manje od 10 godina.

Među osam analiziranih varijanti fasadnih zidova, kao optimalno rešenje nameće se kombinacija zida tipa „YTONG“ sa termoizolacijom od mineralne vune debljine 5 cm.

Potrebno je napomenuti da analizom nije obuhvaćen uticaj degradacije materijala na gubitke u budućem periodu kao ni dodatni gubici koji bi eventualno prosledili usled pojave kondenzacije.

U narednim istraživanjima bilo bi opravdano ponoviti analizu uz projekciju povećanja troškova energenata i manualnog rada s obzirom na tendencije na tržištu pri čemu bi bile uzete u obzir projekcije stanja materijala za posmatrani period.

It was concluded that application of newer types of thermal insulation and products intended for wall construction reduce the losses several times. In addition, certain solutions, compared to non-insulated facade walls, become cost – effective in less than 10 years.

Among eight analyzed types of facade walls, the combination of ‘’YTONG’’ wall and mineral wool thermal insulation of 5 cm imposes as the optimal solution.

It is necessary to mention that the analysis did not comprise the influence of material degradation on the losses in the future, as well as additional losses which would possibly result from the process of condensation.

In the future research projects, it would be justified to repeat the analysis, with the projection of increased costs of energy-generating products and manual work, according to market tendencies, taking into consideration projections of material conditions over the observed period of time.

ZAHVALNOST

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REZIME

IZBOR OPTIMALANOG TIPA FASADNOG ZIDA KORIŠĆENJEM SOFTVERSKOG PAKETA „DESIGNBUILDER“

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Izbor optimalne fasadne konstrukcije postao je nezaobilazan proces prilikom projektovanja savremenih stambenih i poslovnih objekata. Kako je izbor fasadnih sistema u velikoj meri proširen u odnosu na bližu prošlost neophodno je kritički pristupiti oceni varijantnih rešenja. Proces ocene značajno je olakšan primenom specijalnih softverskih paketa. U okviru rada prikazan je primer analize pojedinih rešenja fasadnih zidova sa finansijskog aspekta i aspekta gubitaka toplotne energije uz upotrebu softverskog paketa DesignBuilder v2.0.5.013.

Ključne reči: termičke karakteristike, fasadni zidovi, troškovi, izbor

SUMMARY

CHOOSING AN OPTIMAL TYPE OF FACADE WALL USING ‘’DESIGNBUILDER’’ SOFTWARE PACKAGE

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The choice of optimal facade construction has become an inevitable process when planning contemporary business and residential facilities. Since the choice of facade systems has considerably grown wider compared to recent past, it is necessary to take a critical approach to assessment of variant solutions. The assessment process is significantly facilitated by applying special software packages. The paper presents one example of the analysis of certain solutions of facade walls, from the aspect of both financial and thermal energy losses, by using DesignBuilder v2.0.5.013.software package.

Key words: thermal characteristics, facede walls, costs, choice