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IMPACT OF THE PROPORTION OF GLAZING SURFACE IN SOUTH FACADE ON ENERGY EFFICIENCY OF PREFABRICATED TIMBER BUILDINGS

Vpliv deleža steklenih površin na južni fasadi na energijsko učinkovitost montažnih lesenih stavb

Abstract: The paper presents the reasonability of using an increased proportion of glazing surfaces in prefabricated timber-frame structural systems with a special focus on the energy certification of the building. The research is based on a case study of a two-storey house with a prefabricated timber-frame as well as with cross-laminated structural system with a parametric analysis of an increased-proportion-of-the-glazing-surfaces impact on south side of the building, taking the climate data for Ljubljana into consideration. The analysis was carried out on different exterior wall elements having different thermal properties, while the rest of the parameters, such as the ground plan of the model as well as the active systems, roof and floor slab assemblies remain constant. The graphical presentation includes a function curve showing the annual energy demand for heating and cooling depending on the proportion of the glazing area in relation to the total surface area of the south façade of the building.

Keywords: energy-efficiency, timber building, prefabricated walls, glass.

Povzetek: Prispevek prikazuje smiselnost uporabe povečanega deleža steklenih površin v montažni leseni gradnji s posebnim poudarkom na energijskem izkazu stavbe. Pri tem so parametrično na modelu dvoetažne stanovanjske hiše analizirani vplivi povečanega deleža steklenih površin na južni strani objekta ob upoštevanju klimatskih pogojev za Ljubljano. Objekt je obravnavan v okvirnem in križno lepljenem montažnem sistemu. Analizirani so različni tipi zunanjih sten z različno toplotno izolativnostjo, ostali parametri, kot so tloris objekta, sestava strehe, temeljne plošče, aktivni sistemi, pa v izračunu ne varirajo. Podana je funkcijska odvisnost letnih toplotnih izgub za ogrevanje in ohlajevanje v odvisnosti od deleža steklenih površin na južni fasadi objekta.

Ključne besede: energijska učinkovitost, lesena gradnja, montažne stene, steklo.

1. INTRODUCTION

The present times, characterized by specific circumstances in the sphere of climate change, witness an intensive focus of the sciences of civil engineering and architecture on searching for ecological solutions and construction methods that would allow for greater energy efficiency and, consequently, for a reduced environmental burden. Being a natural raw material, timber represents one of the best choices for energy efficient construction since it also functions as a good thermal insulator, has good mechanical properties and ensures a comfortable indoor living climate. The features listed above make prefabricated timber structures suitable for the construction of energy efficient houses of various standards where an increased proportion and a suitable orientation of the glazing surfa-

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ces play an important part due to solar heat gains. Over a number of years of development, glazing manufacturers have improved their products' thermal-insulation and strength properties as well as their coefficient of permeability of total solar radiation energy and thus enabled the use of large glazing surfaces, primarily south-oriented, not only to illuminate indoor areas but also to ensure solar heating (Johnson et al., 1984; Inanici and Demirbilek, 2000; Bülow-Hübe, 2001; Persson and Roos, 2006; Bouden, 2007; Ford et al., 2007). It follows that timber construction along with the use of suitable and correctly oriented glazing surfaces represents a great potential in residential and public building construction.

The first part of the paper presents principal timber structural systems, such as timber-frame (TF) and cross-laminated timber (CLT) wall elements, as well as essential principles of low-energy construction while the second part focuses on the reasonability of using an increased proportion of glazing surfaces in the above mentioned construction method and adds a parametric analysis of an-increased-proportion-of-the-glazing-surfaces impact in a two-storey house with a prefabricated TF and CLT structural system. The analysis is made only for the south side of the building, while the analysis for other principal directions on the TF 1 structural systems is presented in 2egarac Leskovar and Premrov, 2010. Calculations do not consider various active systems' impacts (heat recovery ventilation, solar collectors, PV panels, heat pumps, etc.). The comparative analysis results can nevertheless serve as a good frame of reference to civil engineers and architects in an approximate estimation of energy losses accompanying the different positioning and proportion of glazing surfaces while using various prefabricated timber-frame wall elements.

2. PREFABRICATED TIMBER HOUSE DESIGN

Timber is commonly associated with lightweight construction although it is ubiquitous as a building material. Timber construction is an important part of the infrastructure in a number of areas around the world. Brand new and improved features, having been introduced in the early 80's of the last century, brought about the expansion of timber-frame buildings all over the world. The most important are the following introduced changes (Premrov, 2008): transition from on-site construction to prefabrication in a factory; transition from elementary measures to modular building and development from a micro-panel to a macro-panel wall prefabricated panel system. All of these extremely improve the speed of building. The brick and concrete industry is responsible for about 10 % of global CO_2 emissions into the environment whereas wood helps the environment by absorbing and storing CO_2 while it grows. Respecting all these facts the energy-efficient properties of timber-frame buildings are, in comparison with other types of buildings, (brick, concrete, steel) excellent but not only because well insulated buildings use less energy for heating, which is environmentally friendly, but also due to the extremely positive feelings of homeowners when living in such houses. There are two main and competitive prefabricated structural systems mostly used in residential timber buildings: a.) a timber-frame system and b.) a massive panel system.

In timber-frame buildings basic vertical load bearing elements are panel walls consisting of load bearing timber frames and sheathing boards. Because all elements are prefabricated (Figure 1a), the erection of such a building is very fast. Development from an old single-panel (Figure 1b) to a new macro-panel wall system (Figure 1a) in the middle of 90's of the last century additionally extremely

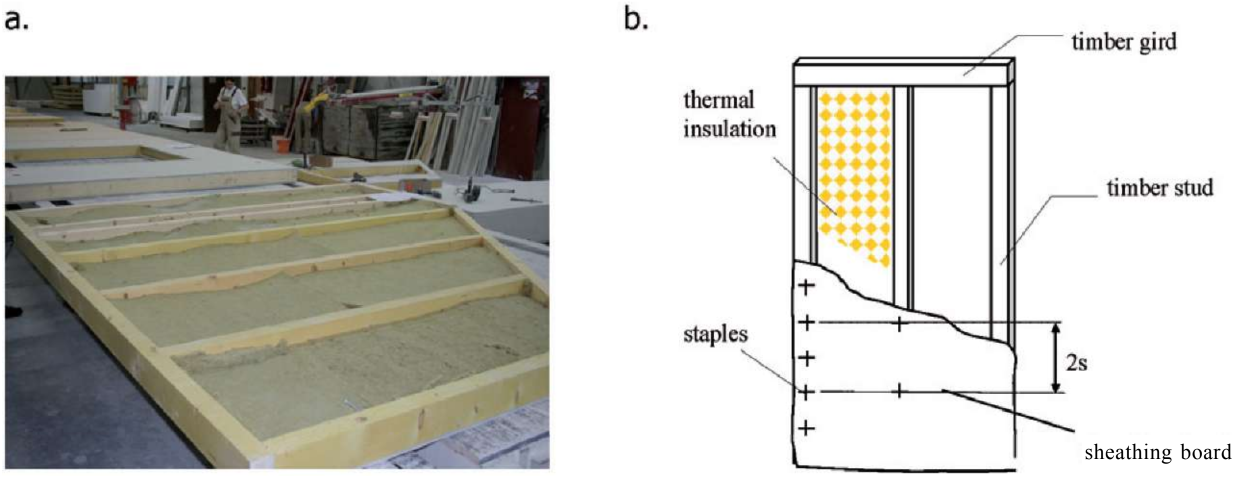

Figure 1: Composition of a timber-frame wall element; a.) macro-panel system, b.) single wall element

enlarges the speed of building. The wall elements in the total length up to 12,5 metres, containing openings for doors and windows, are now completely produced in a factory (Kozem Šilih and Premrov, 2010). The construction performs systematic floor-by-floor building; after the walls are constructed the floor platform for the next level is built. Therefore, this system is very useful and popular for multi-storey buildings and the interest in the world is growing.

Prefabricated timber walls as main vertical bearing capacity elements, of usually typical dimensions with a width b = 1250 mm and a height h = 2500 mm - 2600 mm, are composed of a timber frame and sheets of board-material fixed by mechanical fasteners to both sides of the timber frame (Figure 1b). There are many types of panel sheet products available which may have some structural capacity such as wood-based materials (plywood, oriented strand board, hardboard, particleboard, etc.) or fibre-plaster boards (FPB), originally started in Germany and recently the most frequently used type of board in Central Europe. Between the timber studs and girders a thermo-insulation material is inserted the thickness of which depends on the type of external wall. The sheathing boards on the both sides of the wall can be covered with a 12,5 mm gypsum-cardboard.

Producers usually offer different degrees of energy efficiency of timber-frame buildings. In this study we will treat three main typical wall elements according to different thicknesses of the timber frame and thermal insulation. The main geometrical and material properties are listed in Table 1. Additionally, three old prefabricated single-wall elements (TFkl 4 - TFkl 6; Figure 1b), mainly produced in the early 80s, will be analysed to prove some basic statements.

In a case of massive panel timber buildings the wall elements consist of cross laminated timber boards, well known as "cross-laminated timber" or X-lam, Figure 2. The number of boards are usually 3 or 5 with typical wall width of 90 or 94 mm. Cross laminated timber is a contemporary building material which has more uniform and better mechanical properties than solid timber and therefore presents an architectural challenge and an important trend in a way to assure modern, energy efficient and seismic resistant single family prefabricated houses and multi-storey prefabricated residential timber buildings. Assembling of the building (Figure 2b) runs in a very similar way as by timber-frame buildings and also usually demands very similar time to finish the building.

Producers usually offer different degrees of energy efficiency of massive panel timber buildings. In this study we will treat three main typical wall elements according to different thicknesses of the timber panel and thermal insulation. The main geometrical and material properties are listed in Table 2.

Table 1: Composition of a typical prefabricated timber-frame macro-panel wall elements

TF 1		TF 2		TF 3	
material	thickness [mm]	material	thickness [mm]	material	thickness [mm]
rough coating	6	rough coating	6	rough coating	9
thermal insulation: EPS* foam	100	thermal insulation: mineral wool	100	thermal insulation: woodfibreboard	60
gypsum fibreboard	15	gypsum fibreboard	15	/	
timber frame with insulation: MW**	160	timber frame with insulation: MW	160	timber frame with insulation: CF***	360
vapour barrier	0,2	vapour barrier	0,2	OSB****	15
/	/	timber sub-structure with insulation	60	/	/
gypsum fibreboard	15	gypsum fibreboard	15	/	/
gypsum fibreboard	10	gypsum fibreboard	10	gypsum plasterboard	12.5
total thickness [mm]	306,2	total thickness [mm]	366,2	total thickness [mm]	456,5
U_{wall}-value [W/m^{2}K]	0,164	U_{wall}-value [W/m^{2}K]	0,137	U_{wall}-value [W/m^{2}K]	0,104

* expanded polystyrene foam, ** mineral wool, ***cellulose fibre, ****oriented strand board

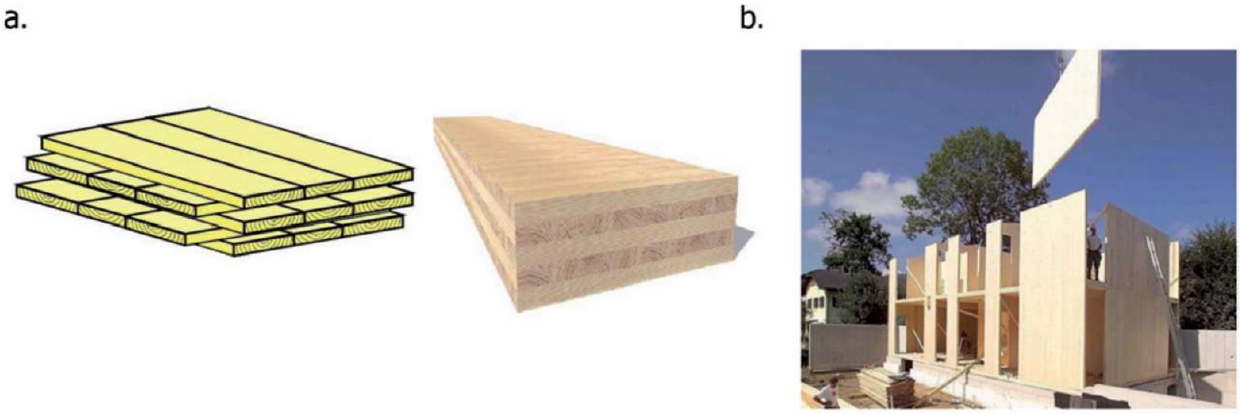

Figure 2. a.) Composition of cross-laminated panels (Dujič and Žarnič, 2009)
b.) Erection of the house built in massive panel system.

Table. 2: Composition of a typical prefabricated massive panel wall elements.

KLH 1		KLH 2		KLH 3	
material	thickness [mm]	material	thickness [mm]	material	thickness [mm]
rough coating	6	rough coating	6	rough coating	6
thermal insulati-on: MW*	180	thermal insulati-on: MW*	180	thermal insulati-on: MW*	220
cross laminated timber	95	cross laminated timber	95	cross laminated timber	142
/	/	timber sub-struc-ture with thermal insulation: MW*	60	timber sub-struc-ture with thermal insulation: MW*	60
gypsum fibre-board	15	gypsum fibre-board	15	gypsum fibre-board	15
gypsum fibre-board	10	gypsum fibre-board	10	gypsum fibre-board	10
total thickness [mm]	306	total thickness [mm]	366	total thickness [mm]	453
U_{wall}..-value [W/m^{2}K]	0,181	U_{wall}..-value [W/m^{2}K]	0,148	U^{wall}-value [W/m^{2}K]	0,124

* mineral wool, **expanded polystyrene foam

3. BASIC REQUIREMENTS OF ENERGY EFFICI-ENT HOUSE DESIGN

The definition of an energy efficient house is related to the specific design approach comprising exactly defined parameters which influence the energy balance of residential houses. The basis of energy efficient house design is to take advantage of as many renewable energy sources combined with low energy technology as possible in order to reduce the need for traditional building technology which is inefficient or consumes a lot of fossil fuel energy. There are few classifications of energy efficient houses that differ from each other minimally, but in general they comprise a group of houses with exactly defined energy standards. For example a low-energy house is a house with an annual requirement for energy used for heating of less than 50 kWh/m^{2}a, however the requirements differ from one country to another, while for a passive house this requirement is strictly defined with the value being lower than 15 kWh/m^{2}a in all countries. In a low-energy house the specified low energy consumption can be achieved by reducing heat flow through the

Table 3: Classification of energy efficient houses on the basis of "Rules on the methodology of construction and issuance of building energy certificates", 2009, and Praznik and Kovič, 2010.

Degree / Classification in accordance with the rules	Generally used classification in praxis	Annual heating demand Q_h [kWh/m^{2}a]	Variation of execution
Class C	minimal requirements for low-energy house	40 - 50	classic/conventional building envelope
Class B2	low-energy house	25 - 40	thermally improved building envelope
Class B1	better low-energy house	15 - 25	thermally improved building envelope + HRV*
Class A2	passive house	10 - 15	additionally thermally improved building envelope + HRV
Class A1	1-litre house	< 10	additionally thermally improved building envelope + HRV + improved U-value of windows and doors

*heat recovery ventilation

envelope by installing sufficient thermal insulation and thermally efficient glazing with well designed shading. Although the use of a ventilation system with heat recovery as well as improved heating systems in connection with solar panels and heat pumps is recommended, some conventional heating systems are still acceptable. Besides the above listed technical specifications the compact form of the building and its southern orientation is of great importance. The compact form of the building reduces the total envelope area which results in lower transmission heat losses. On the other hand in passive houses a comfortable living environment is achieved without using conventional heating and cooling systems. The basis of passive house design is to take advantage of passive technologies as much as possible in order to reduce the need for the energy provided by fossil fuel. The passive design technologies and systems include excellent envelope insulation, air tightness, triple glazing, construction without thermal bridges and passive solar design which is preconditioned by appropriate southern orientation with well designed shading. On the other hand, active house design systems include heat recovery ventilation, ground source heat pumps, lightning with low energy lamps and more. Classification of energy efficient buildings according to different variation of execution is presented in Table 3.

4. NUMERICAL STUDY

4.1. SIMULATION MODEL

Description of the base case study model:

A model of the two-storey single-family house was designed using a low-energy standard. The external horizontal dimensions are 11,66 x 8,54 m for the ground floor and 11,66 x 9,79 m for the upper floor. The total heated floor area is 168 m^2, Figure 3.

Glazing:

A window glazing (Unitop 0,51 - 52 UNIGLAS) with three layers of glass, two low emissive coatings and krypton in the cavities for a normal configuration of 4E-12-4-12-E4, each cavity 12 mm thick, with 4 mm thick glass panes, was installed. The glazing configuration with a g-value of 52 % and a U-value (U_g) of 0,51 W/m^{2}K assures a high level of heat insulation and light transmission (UNIGLAS College, 2010). The window frame U-value (U_f) is 0,73 W/m^{2}K, while the frame width is 0,114 m. The glazing to wall area ratio (AGAW) of the south oriented façade is 27,6 %, while the AGAW values of the rest of the cardinal directions are 8,9 % in north, 10,5 % in east and 8,5 % in west façades.

Climate and orientation:

The house is located in Ljubljana and oriented with the longer side with the large glazed area facing south. The city of Ljubljana is located at an altitude of 298 metres, latitude of 46.03° and longitude of 14,3° east. According to data from ARSO, Ljubljana's climate is Subalpine.

Shading:

The house is constructed with a south-oriented extended overhang above the ground floor, which blocks the direct solar radiation from entering the ground floor windows to the south during the summer, while it lets it

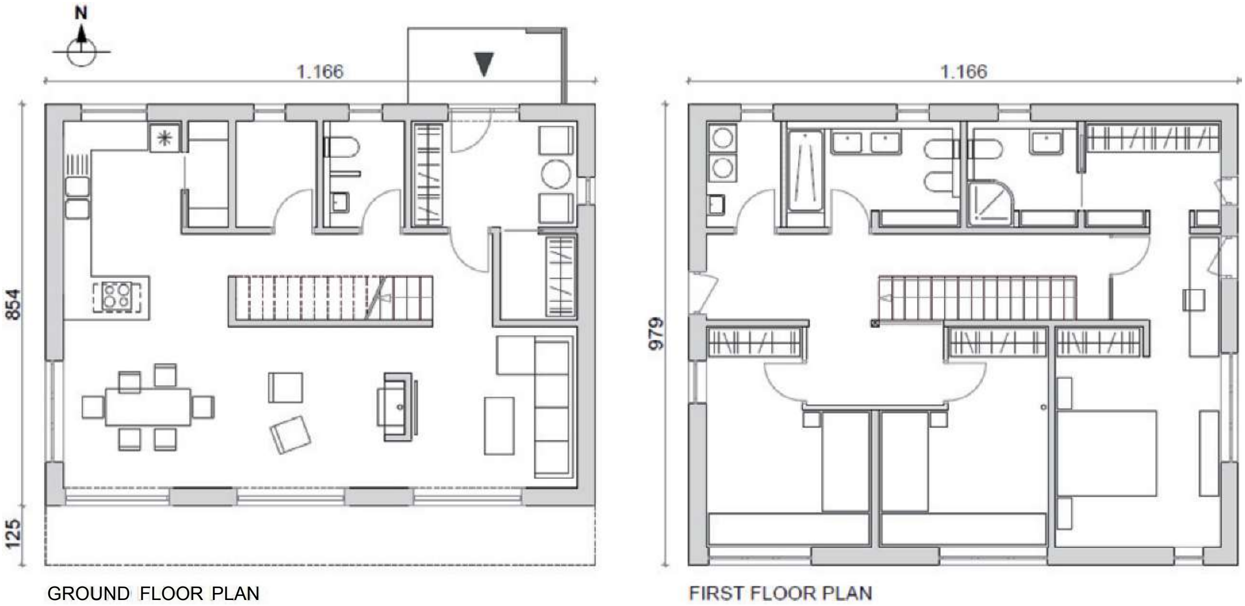

Figure 3: Ground plan of base-case study model

enter in winter when the angle of incidence of the sun is lower. The rest of the windows on the upper floor and those of the east, west and north-oriented walls are shaded with external shading devices. To avoid results that would not be objective, we decided to shade the north facing glazing areas as well.

Internal gains and HVAC:

The length of the heating period is 205 days. A value of 2,1 W/m^2 for internal heat gains from electric appliances and body heat was used in the PHPP (internal heat sources) calculation. To prevent overheating in the summer period the summer operation of the heat recovery ventilation with an air change rate of 0,30 h^{-1} was planned. Additional summer ventilation for cooling through manual window night ventilation with an air change rate of 0,15 h^{-1} was planned as well. The interior temperatures were designed to a T_{min} of 20°C and a T_{max} of 25°C. No solar collectors were installed.

Parameters varied:

The influence on energy demand of the following factors was studied: glazing size in four different cardinal directions; south, north, east and west. Modifications were made separately for each cardinal direction for six timber systems; TF 1, TF 2, TF 3 and only for south-oriented glazing areas for three additional systems (TFkl 4, TFkl 5 and TFkl 6) with higher U-values (U_{14} = 0,70 W/m^{2}K, U_5 = 0,45 W/m^{2}K and U_{16} = 0,30 W/m^{2}K) which are typical for older timber systems built with single-panel wall elements. The modifications of the size of glazing areas were in the range of AGAW (glazing to wall area ratio) of 0 % to nearly 80 %, Figure 4.

Object of the research:

As already presented previously the object of the research was the definition of the most favorable glazing to wall area ratio for each cardinal direction of the house. The results observed in the PHPP calculations were heating demand and cooling demand values.

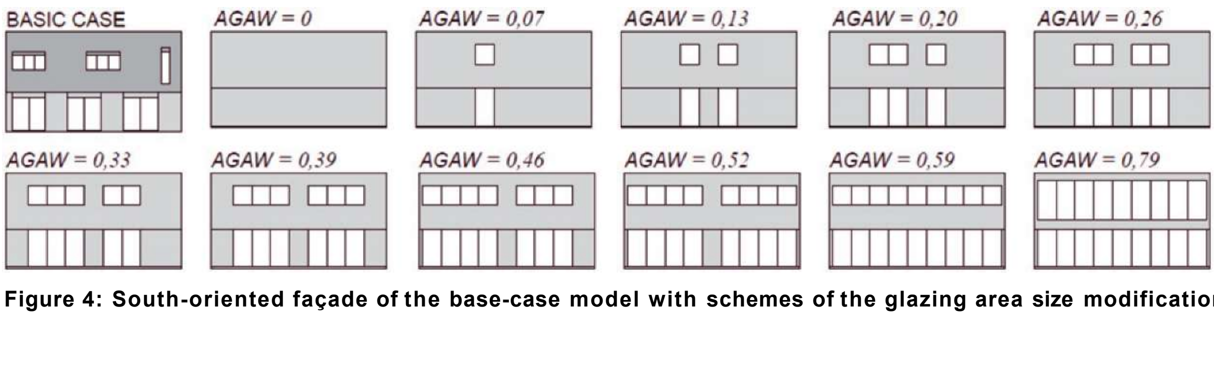

Figure 4: South-oriented façade of the base-case model with schemes of the glazing area size modification.

Description of the software and calculation method:

The Passive House Planning Package 2007 (Feist, 2007) was used to perform calculations of energy demand. The software is certified as a planning tool for passive houses, although it can be used also for low-energy house design.

4.2. RESULTS AND DISCUSSION

4.2.1. Timber - frame (TF) structural systems

The behaviour of the TF 1, TF 2 and TF 3 systems for north, west and east direction is very similar because no Q_h gains are appearing for this orientations (2egarac Leskovar and Premrov, 2010), therefore only the south direction, which is the main point of our special interest, will be additionally analysed and compared for all construction systems. The results in Figure 5 are presented separately for Q_h energy demand (Figure 5a) and total annual energy demand for heating and cooling (Figure 5b).

The results show almost linear functional dependence of Q_h on the size of the glazing area. Observation of the results shows also that the energy demand for heating is the highest in the TF 1 and lowest in the TF 3 construction system, which we suppose is related to the U-value of external wall elements. The results for sum total energy demand show an interesting appearance related to the optimal point with the lowest *(Q_h+Q_l)* demand (functional optimum), which is clearly evident in the TF 3 construction system appearing at the range of *AGAW = 0,34 to 0,38* and slightly less evident in the TF 1 system. For comparison purposes as well as for support in setting up the basic principle of the glazing surface's impact on energy behaviour patterns, an analysis of the classic single-panel prefabricated wall elements was carried out. The results for TFkl 4 - 6, compared with the results for macro-panel systems, are presented in Figure 6.

According to the data presented in Figure 6a an expressive linear functional dependence of Q_h from AGAW for TFkl systems is evident, while the inclination of the function lines presenting TF systems is smaller. It is evident that the thermal transmittance of the exterior wall element plays an important role; the higher is the U-value (TFkl) greater and more favourable is the influence of the glazing area increase for the energy demand for heating. The comparison of energy savings for heating for two extreme systems regarding to *U_{wall}-value,* shows significant difference; a saving of 39 kWh/m^{2}a for TFkl 4 and only 12 kWh/m^{2}a for TF 3, which has the best insulating features. From the results presented above we infer that the increase of the south oriented glazing areas in external wall elements of lower insulation features (higher U-value) has greater influence on Q_h compared to the glazing modifications in wall elements of better insulation features (lower U-value). This confirms the statement mentioned in the text above, that the influence of the glazing area increase to the energy demand for heating is more favorable in external wall elements with a higher U-value.

The analyses of the sum of total heating and cooling demand presented (Figure 6b) seems to be the most interesting; in the case of exterior wall elements with a higher U-value the functional optimum doesn't appear at all, the energy demand behaviour changes from parabolic dependence in construction systems with a low U-value

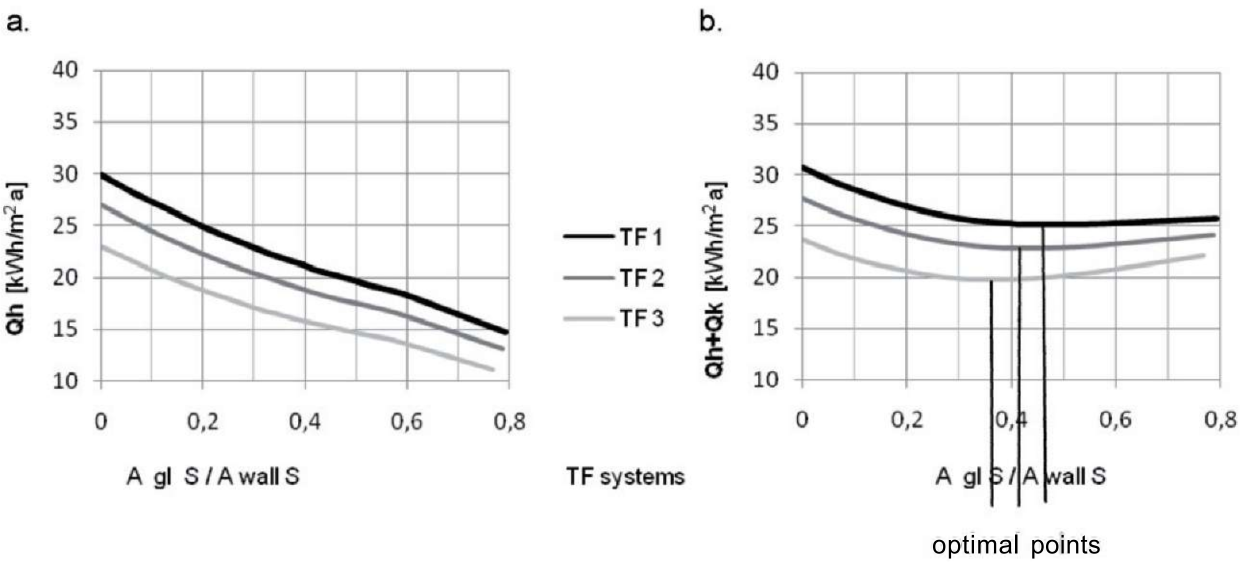

Figure 5: Energy demand: a.) for heating and b.) sum total of energy demand for heating and cooling as a function of AGAW in TF 1 construction system.

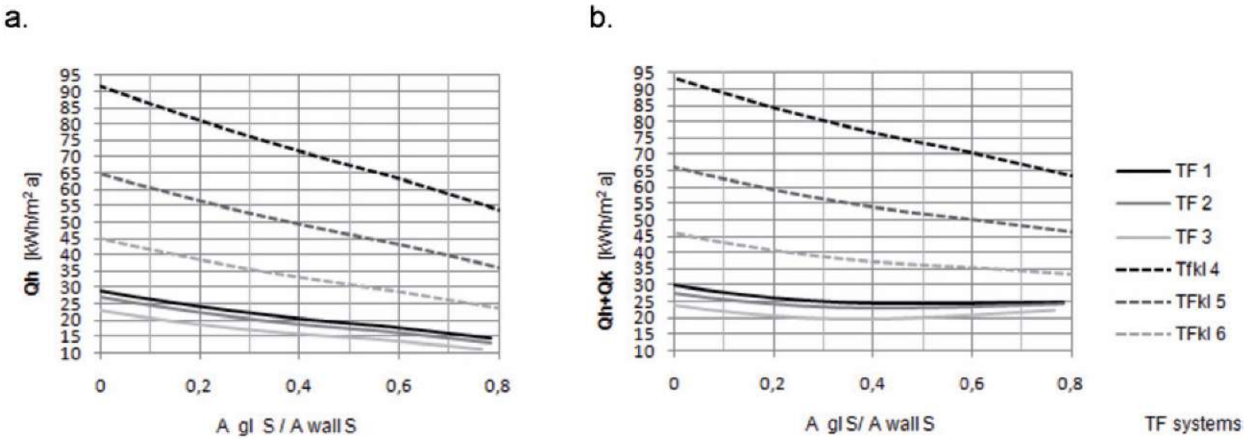

Figure 6: Comparison of energy demand a.) for heating and b.) sum total of energy demand for heating and cooling as a function of AGAW in TF construction systems.

(TF 2 and TF 3) to linear dependence in construction systems with lower insulation features (TFkl 4 - TFkl 6). It is evident that the inclination of a function line presenting TFkl systems depends on the U-value, which is similar to the analysis of the Q_h demand. Energy savings caused by total glazing area increase (from *AGAW=0* to *AGAW~0,79)* are in the range from approximately 31 kWh/m^{2}a or 33 % of the starting point value for the TFkl 4 system to only 12 kWh/m^{2}a or 27 % for the TFkl 6 system. In comparison to the TF 3 system which has the highest insulation features the difference is even greater.

4.2.2. Massive panel structural systems (KLH)

Comparison of energy demand for heating (Q_h) and for heating and cooling (Q_h+Qj) for different construction systems (TF1 - TF 3 and KLH 1 - KLH 3) is presented in Figure 7.

According to the results presented in Figure 7a the behaviour of energy demand for Q_h and Q_h+Q_k is similar for TF and KLH construction systems. As already seen in the previously analysed comparison of selected TF construction systems, the increase of the south oriented glazing area in wall elements with a higher thermal transmittance as well as in wall elements with a lower thermal transmittance is similar. On the basis of this research, we anticipate that U-value of the external wall has no distinctive impact to the behaviour of the energy demand for cooling, it depends more on the size of a glazing area as well as on orientation and of course on other parameters which are not analysed in this research.

According to the results presented in Figure 7b the energy savings in the KLH 1 construction system reach about 6 kWh/m^{2}a or 19 % of the starting point value, while in the

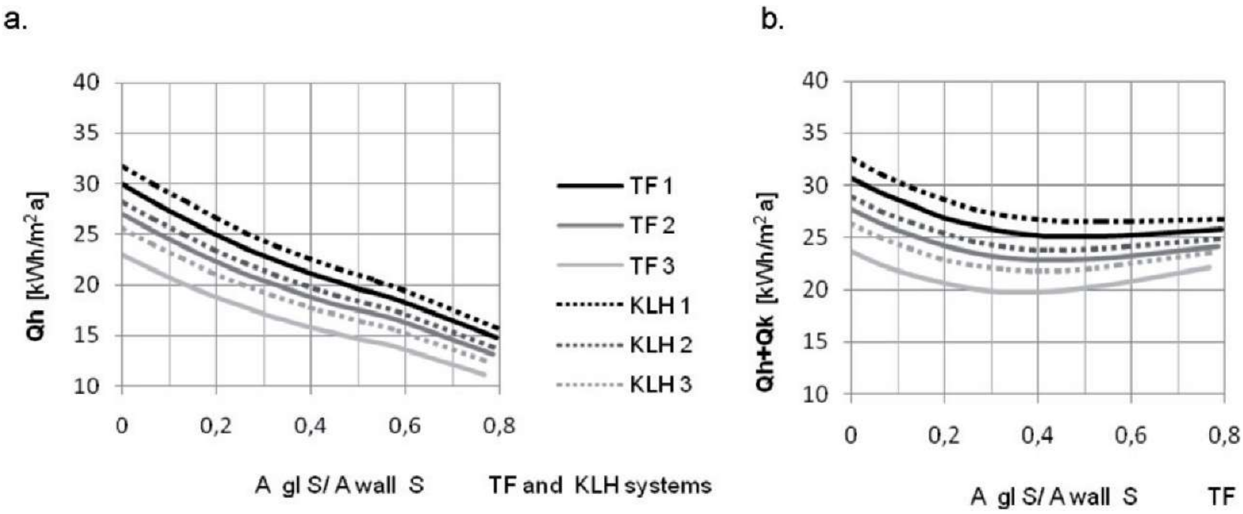

Figure 7: Comparison of energy demand a.) for heating and b.) sum total of energy demand for heating and cooling as a function of AGAW in TF and KLH construction systems.

TF 3 construction system, which possesses the best thermal properties among analysed systems, the savings of only about 4 kWh/m^{2}a or slightly over 16 % are evident. The further observation of the results shows for compared construction systems shows that the optimal point appears at different values for *AGAW* in each individual system. In KLH 3 the optimum appears at AGAW = *0,38- 0,40,* in KLH 2 at AGAW = *0,41 - 0,46,* in KLH 1 at AGAW = *0,52 - 0,54,* in TF 3 at AGAW = *0,34 -0,38,* in TF 2 at AGAW = *0,41* and finally in TF 1 at AGAW = *0,42 - 0,50.* The analyses of formerly presented results shows that the optimal glazing share is larger for the exterior wall elements with a higher U-value reaching the maximal optimal share of 54 % of the total south oriented external wall surface in KLH 1, while it is somewhat lower for exterior wall elements with a lower U-value, reaching the minimal share of 34 % in the TF 3 construction system. Next, the form of the Q_h+Q_k function curve in different systems was analysed as well, the optimal point is clearly evident in systems with a lower U_{wall}-value, where the sum of total energy demand increases noticeably after reaching the optimum, while the optimum is less expressive in systems with a higher U_{wal}-value, where the function curve converges after reaching the optimum. If applied to praxis this means that for exterior wall elements with excellent thermal properties (U_{wall} ~ *0,1 - 0,124* W/m^{2}K) the optimal share of glazing is strictly defined, while for wall elements of higher U-values *(U_{wall} ~ 0,164 - 0,181* W/m^{2}K), the glazing share can exceed the optimal value without any noticeable consequences regarding increase of the sum total of energy demand for heating and cooling. The optimal *AGAW* values for all analyzed systems as a function of U_{wall}-value are numerical presented in Table 4.

Table 4: Optimal values of AGAW in south oriented external wall element for selected timber construction systems.

Construction system	U_{wall} [W/m^{2}K]	$AGAW_{optimal}$	$AGAW_{optimal}$ adjusted
TF 3	0,102	0,34 - 0,38*	0,37
KLH 3	0,124	0,38 - 0,40	0,39
TF 2	0,137	0,41	0,41
KLH 2	0,148	0,41 - 0,46	0,43
TF 1	0,164	0,42 - 0,50	0,47
KLH 1	0,181	0,52 - 0,54	0,53
SYSTEMS**	>0,20	=0,80	0,80

*at *AGAW = 0,38* overheating is lower than at *AGAW = 0,34*

**for the construction systems with a U_{wall} > 0,20 W/m^{2}K the optimum is at *AGAW~ 0,80* (Figure 6b)

5. CONCLUSIONS

It is evident from the results presented for the total annual energy demand (Qh+Q^) of classical old single-panel construction systems (TFkl) that an increase in the south-oriented glazing areas in exterior walls with a higher thermal transmittance adds up to the sum total of energy savings. This is especially important for the refurbishment of existing timber-frame housing stock, since the use of large glazing areas in south-oriented external walls improves the energy efficiency of the building.

The influence of glazing in new low-energy prefabricated timber-frame (TF) as well as in massive panel systems (KLH) is less evident. The behaviour of energy demand for heating (Q_h) and also for heating and cooling (Q^+Q^ is similar for TF and KLH construction systems. Additionally, the comparison of function curves shows an interesting appearing of the optimal point with the lowest *Q_h+Q_k* demand. The optimal point of Q_h+Q_k in the TF3 construction system with the lowest Uwall-value is clearly evident and appears in the range of *AGAW = 0,34 to 0,38.* The optimal point is slightly less evident in the TF 1 and KLH 1 structural systems, which demonstrates that the optimal share of glazing surfaces in south-oriented exterior walls depends on the thermal transmittance of the exterior wall.

Therefore, according to the given states, we can conclude, that the optimal proportion of glazing surface in wall elements with a lower U-value is somewhat lower than that of the wall elements with a higher U-value. If we pay attention to the behaviour of the (Q_h+Q_k) function curve after reaching the optimal point, we notice that the sum of total energy demand for heating and cooling increases in highly insulated construction systems, while in wall elements with a higher U-value the function converges, which means that even if the glazing share exceeds the optimum, almost no increase in (Q_h+Q_k) is noticeable.

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O AVTORICI PRISPEVKA DR. VESNA ŽEGARAC LESKOVAR

Vesna 2egarac Leskovar (rojena 1974) je predavateljica na Fakulteti za gradbeništvo Univerze v Mariboru (UM FG). Leta 2000 je zaključila dodiplomski študij arhitekture na Fakulteti za arhitekturo Univerze v Ljubljani. Po zaključenem študiju je bila zaposlena v podjetju Reichenberg Arhitektura d.o.o v Mariboru, v katerem je delovala predvsem na področju arhitekturnega in urbanističnega načrtovanja. Od leta 2005 je zaposlena na UM FG, sprva kot asistentka, leta 2008 je bila izvoljena v predavateljico za predmetni področji Arhitektura in Prostorsko načrtovanje. V januarju 2011 je na Fakulteti za arhitekturo Tehniške univerze v Gradcu v Avstriji uspešno zagovarjala doktorsko disertacijo z naslovom »Pristop k oblikovanju optimalnega modela energijsko učinkovite lesene hiše«. V okviru Fakultete za gradbeništvo je njeno delo povezano z raziskavami na področju energijsko učinkovite lesene gradnje, prav tako omenjeno tematiko vključuje v pedagoški proces, predvsem na področju študijskih delavnic, ki jih na fakulteti izvaja v sodelovanju s priznanimi slovenskimi podjetji. Je članica skupine Structural Glass - Novel Design Methods and Next Generation Products, v okviru katere sodeluje pri pripravi izobraževalnega gradiva za področje energijske učinkovitosti steklenih površin. Svoje delo predstavlja na domačih in mednarodnih konferencah, prav tako pa je sodelovala pri organizaciji prvega mednarodnega posveta Energijska učinkovitost v arhitekturi in gradbeništvu, ki je potekal pod okriljem UM FG in Društva inženirjev in tehnikov Maribor leta 2010 v Mariboru.

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