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BRNO UNIVERSITY OF TECHNOLOGY

FAKULTA STAVEBNÍ

FACULTY OF CIVIL ENGINEERING

ÚSTAV POZEMNÍHO STAVITELSTVÍ

INSTITUTE OF BUILDING STRUCTURES

SAMOSTATNÉ RODINNÉ BYDLENÍ

DETACHED FAMILY RESIDENCE

BUILDING PHYSICS

BAKALÁŘSKÁ PRÁCE

BACHELOR'S THESIS

AUTOR PRÁCE
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BRNO 2018

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1. General information about the construction

Name of the building:	Detached family residence
Location of the building:	Brno-Královo Pole
	Sadová 333
	St. Miry Figarové
	Parcel number: 251/6

The aim of the investor is to design a family house for permanent residence of 5 family members. The building is designed from wooden construction, the loadbearing elements are STEICO columns with maximum distance of 625 mm. The construction is filled with mineral wool ISOVER WDF plus and covered with OSB thickness 15 mm. On the internal side there is 60 mm of ISOVER UNI which is covered by gypsum board. The external side is made of ventilated façade, the finish elements are cement fiber boards EQUITONE. The load bearing walls are constructed on foundation strips. The house has a flat roof. The entrance is oriented on the South side.

2. Materials for process

- Architectural study of bachelor project including text parts
- Working version of project in realization phase
- Catalogue information of the construction materials
- List of the compositions of constructions

3. Used norms and regulations

The following norms and regulations were used:

- ČSN 73 0540-1:2005 Thermal protection of buildings – Part 1: Terminology
- ČSN 73 0540-2:2011 + Z1:2012 Thermal protection of buildings – Part 2: Requirements
- ČSN 73 0540-3:2005 Thermal protection of buildings – Part 3: Recommended values
- ČSN 73 0540-4:2005 Thermal protection of buildings – Part 4: Calculation methods
- ČSN 73 0532 - Acoustics. Assessment of sound insulation of building structures in buildings, requirements.

4. Technical parameters of the building

a. Climatic information of the area side conditions in exterior and interior part

Parcel number:	251/6
Municipality:	Brno [582786]
Cadastral territory:	Sadová [611565]
Number LV:	927
Area [m^2]:	543
Altitude:	292,115 m.a.s.l.

Air conditions:

Proposed outdoor temperature in winter θe= -15 °C

Proposed indoor temperature in winter θi= 20 °C

Relative indoor humidity 50%

Volume of building- external volume of building heated zone: 868,14 m^2

b. Characteristics of cooled constructions

EXTERNAL LOAD-BEARING WALL th. 560 mm

External load-bearing walls are made from load-bearing STEICO joist SW60, which are constructed with the maximum distance of 625 mm and is filled with mineral wool ISOVER WDF plus.The external sheeting is from OSB 15 mm. On the internal side there is 60 mm of ISOVER UNI made from 60 x 60mm wooden battens which is covered by gypsum board. On the external side of the wall a construction there are wooden battens 60 x 60 mm and the space is filled with mineral wool naturboard 032. Air layer made by 30 x 60 mm from wooden battens is finished by EQUITONE picture cement fiber boards.

FLOOR ON THE GROUND

The ground floor has two different floor finishes, ceramic tiles and wood flooring. Underlay is made from MIRELON, which is placed on concrete layer thickness 50 mm. The insulation layer is from ISOVER EPS 100S thickness 300 mm which is placed on reinforce concrete slab th. 200 mm.

FLAT ROOF

The load-bearing construction is from STEICO joist with thickness of 240 mm. The sheeting is from OSB thickness 12 mm. This layer is then filled with ISOVER UNIROLL plus with total thickness of 240 mm. On the top there is insulation layer and it is made from ISOVER EPS 100S with total thickness of 300 mm. Gradient is made from polystyrene STYRO EPS 150S and the finish layer is FATRAFOL foil 807.

5. Characteristic of structure with requirements on air soundproof

INTERNAL PARTITION WALL th. 125 mm

Partition walls are made from wooden studs 60/100 mm, which are sheeted by gypsum board th. 12.5 mm. Maximum axis distance of studs is 625 mm. Partitions are filled with glass mineral wool ISOVER AKUPLAT+.

Rw = 46 ….. Given from the distributor ISOVER

R'w = Rw – 2 = 44 dB

R'w > Rw,n

44 dB > 42 dB … SATISFACTORY

CEILING ABOVE 1.ST FLOOR.

Ceiling is made from load-bearing STEICO SJ joists, thickness 240 mm. The space between the joists is filled with mineral wool ISOVER PIANO thickness 120 mm. The construction is sheeted only on the top side with OSB thickness 22 mm. Impact sound insulation is made from ISOVER EPS rigifloor with total thickness of 50 mm which is then covered with OSB thickness 25 mm. The finish layer is either laminate flooring or ceramic tiles. See composition of structures for more details.

Rw = 52 dB , Lnw = 67 dB

R'w > Rw,n

R'w = Rw – k = 52 – 4 = 48 dB

48dB > 47 dB … SATISFACTORY

L'nw = Lnw – k = 67 – 2 = 65 dB

65 dB > 63 dB … SATISFACTORY

6. Requirements of norms – heat distribution in construction, air soundproof

Requirements on heat distribution in construction according ČSN 73 0540 and requirements on air soundproof according to ČSN 73 0532 are included in particular calculations (tables). Results of calculations are compared with these requirements.

7. Data about fulfillment of norms requirements

a. According to thermal protection of building

F1- Floor structure of heated space adjacent to soils

1. Calculation of thermal resistance of given structure

Table.1: Floor finish wood floor

No.	Material	d [m]	λu [W/m.K]	Rj [m²K/W]
1	Wood floor skander	0,012	0,21	0,057
2	Mirellon insulation underlay	0,003	0,46	0,003
3	Concrete layer	0,05	1,25	0,04
4	PE separation layer	-	-	-
5	ISOVER EPS 100S	0,3	0,037	8,108
6	Waterproofing bitumen strip	-	-	-
7	Reinforced concrete	0,2	1,266	1,266
	Total			**9,474**

Table.2: Floor finish ceramic tiles

No.	Material	d [m]	λu [W/m.K]	Rj [m²K/W]
1	Ceramic tile ege buxy	0,01	1,11	0,009
2	Adhesive S-line	0,005	0,96	0,005
3	Concrete layer	0,05	1,25	0,04
4	PE separation layer	-	-	-
5	ISOVER EPS 100S	0,3	0,037	8,108
6	Waterproofing bitumen strip	-	-	-
7	Reinforced concrete	0,2	1,266	1,266
	Total			**9,428**

2. Calculation of thermal resistance of structure

Rt= Rsi + Σ R + Rse = 0,17 + 9,474 + 0,04 = 9,68 m^2.K/W

Rt= Rsi + Σ R + Rse = 0,17 + 9,428 + 0,04 = 9,64 m^2.K/W

Where

RT is thermal resistance of given structure [m^2.K/W]

Rsi is internal surface resistance [m^2.K/W]

Σ R is sum of thermal resistances of individual layers [m^2.K/W]

Rse is external surface resistance [m^2.K/W]

3. Calculation of heat transfer coefficient

U = 1/Rt = 1/ 9,68 = 0,103 [W/m^2.K]

U = 1/Rt = 1/ 9,64 = 0,103 [W/m^2.K]

Where

U is heat transfer coefficient [W/m^2.K]

RT thermal resistance of given structure [m^2.K/W]

U ≤ UN,20 …

0,103 < 0,24 W/m^2.K … SATISFIED

F5- Flat roof above 2nd floor

1. Calculation of thermal resistance of given structure

Table.3: Flat roof composition

No.	Material	d [m]	λu [W/m.K]	Rj [m²K/W]
1	Fatrafol foil	-	-	-
2	Gradient polystyren	-	-	-
3	ISOVER EPS 100S	0,3	0,037	8,108
4	Waterproofing bitumen strip	-	-	-
5	OSB	0,012	0,13	0,092
6a	Steico joist	0,24	0,15	
6b	ISOVER uniroll plus	0,24	0,036	6,389
7	OSB	0,012	0,13	0,092

The following R value was obtained using software THERM 7.6

R = 14,22 m2K/W

2. Calculation of thermal resistance of structure

Rt= Rsi + Σ R + Rse = 0,1 + 14,22 + 0,04 = 14,36 m^2.K/W

Where

RT is thermal resistance of given structure [m^2.K/W]

Rsi is internal surface resistance [m^2.K/W]

Σ R is sum of thermal resistances of individual layers [m^2.K/W]

Rse is external surface resistance [m^2.K/W]

3. Calculation of heat transfer coefficient

U = 1/Rt = 1/ 14,36 = 0,07 [W/m2.K]

Where

U is heat transfer coefficient [W/m2.K]

RT thermal resistance of given structure [m2.K/W]

U ≤ UN,20 …

0,07 < 0,24 W.m-2.K-1 … SATISFIED

W1- PERIPHERAL WALL IN CONTACT WITH EXTERIOR AIR

1. Calculation of thermal resistance of given structure

Table.4: Composition of peripheral wall

No.	Material	d [m]	λu [W.m-1.K-1]	Rj [m2K/W]
1	EQUITONE cement fiber panel	0,008	0,173	0,046
2a	Air layer	0,03	0,147	0,2
2b	Wooden battens (30x60)	0,03	0,41	0,073
3	Damp proof membrane	-	-	-
4a	Mineral wool Naturboard 0.32	0,06	0,035	1,714
4b	Wooden battens (60x60)	006	0,41	0,146
5	OSB	0,015	0,13	0,092
6a	Steico joist	0,36	0,15	-
6b	ISOVER WDF plus	0,36	0,032	11,25
7	OSB	0,015	0,13	0,115
8a	Wood battens (60x60)	0,06	0,41	0,146
8b	ISOVER UNI	0,06	0,035	1,714
9	Gypsum board	0,0125	0,21	0,006

The following R value was obtained using software THERM 7.6

R = 10,89 m2K/W

2. Calculation of thermal resistance of structure

Rt= Rsi + Σ R + Rse = 0,13 + 10,89 + 0,13 = 11,15 m2.K/W

Where

RT is thermal resistance of given structure [m2.K/W]

Rsi is internal surface resistance [m2.K/W]

Σ R is sum of thermal resistances of individual layers [m2.K/W]

Rse is external surface resistance [m2.K/W]

3. Calculation of heat transfer coefficient

U = 1/Rt = 1/ 11,15 = 0,09 [W/m2.K]

Where

U is heat transfer coefficient [W/m2.K]

RT thermal resistance of given structure [m2.K/W]

U ≤ UN,20 …

0,09 < 0,30 W.m-2.K-1 … SATISFIED

b. Heat transfer coefficient of windows

Uw = (Uf . Af + Ug . Ag + ψg . Ig) / (Af + Ag))

Where

- Uw is heat transfer coefficient of whole window [W/m2.K]
- Uf is heat transfer coefficient of window frame [W/m2.K]
- Af is total area of a frame [m2]; 19,2 % of total area of window (Af + Ag)
- Ug is heat transfer coefficient of window glazing [W/m2.K]
- Ag is total area of window glazing [m2]; 80,8 % of total area of window (Af + Ag) ψg is linear factor of heat transfer, ψg = 0,03-0,08; we take 0,06 [W/m.K]
- Ig is visible perimeter of glazing [m]

Designed windows: INTERNORM KF410, triple glazing, aluminium/plastic

Uf= 0,96 [W/m2.K]

Ug=0,6 [W/m2.K]

ψg = 0,06 [W/m.K]

Designed curtain wall: wooden mullions THERM+ H-I, triple glazing

Uf= 0,85 [W/m2.K]

Ug=0,6 [W/m2.K]

ψg = 0,06 [W/m.K]

Table.5: Window openings

Sign	b [m]	h [m]	A [m^2]	Ag [m^2]	Af [m^2]	Ig [m]	Uw [W/m^2]
01	2,40	2,40	5,76	4,40	1,36	8,80	0,78
02	1,50	0,70	1,05	0,65	0,40	3,60	0,94
03	0,60	0,50	0,30	0,12	0,18	1,40	1,10
04	0,60	0,90	0,54	0,28	0,26	2,20	1,02
05	1,14	2,50	2,84	2,15	0,69	6,47	0,82
06	4,50	2,50	11,25	10,11	1,14	13,20	0,70
07	2,40	2,50	6,00	4,42	1,58	9,00	0,78
08	2,40	2,50	6,00	4,42	1,58	9,00	0,78

All constructions are assessed according to ČSN 73 0540 and must meet condition

U ≤ UN, 20 [W / m2 • K]

Where

- b is width of the window [m]
- h is height of the window [m]
- A is the total area of the window [m2]

c. Heat transfer coefficient of doors

Uw = (Uf . Af + Ug . Ag + ψg . Ig) / (Af + Ag)

Where
- Uw is heat transfer coefficient of whole door [W/m2.K]
- Uf is heat transfer coefficient of door frame [W/m2.K]
- Af is total area of a frame [m2]; about 90% in entrance doors, otherwise 100% of total area of door (Af + Ag)
- Ug is heat transfer coefficient of door glazing [W/m2.K]
- Ag is total area of door lazing [m2]; about 10% in entrance doors, otherwise 0% of total area of door (Af + Ag)
- ψg is linear factor of heat transfer, ψg = 0,03-0,08; we take 0,06 [W/m.K]
- Ig is visible perimeter of glazing [m]

Entrance doors: ALUPROF MB-104 Passive, aluminium frame

Uf=0,75 [W/m2.K]

Ug=0,5 [W/m2.K]

ψg = 0,06 [W/m.K]

Sliding doors: ALUPROF MB-77, aluminium frame

Uf=0,75 [W/m2.K]

Ug=0,5 [W/m2.K]

ψg = 0,06 [W/m.K]

Table.6: Door openings

Sign	b [m]	h [m]	A [m^2]	Ag [m^2]	Af [m^2]	Ig [m]	Uw [W/m^2]
08	1,45	2,50	3,63	0,50	3,13	7,10	0,85
07	2,4	2,4	5,76	4,4	1,36	8,8	0,73

All constructions are assessed according to ČSN 73 0540 and must meet condition

U ≤ UN, 20 [W / m2 · K]

Where
- b is width of the window [m]
- h is height of the window [m]
- A is the total area of the window [m2]

d. Check of heating factor on construction surface

All constructions are assessed according to ČSN 73 0540. For calculations the relative humidity of the air is assumed to be 50%. In winter, the construction must meet the temperature factor of the inner surface at each location.

The lowest internal surface temperature and the temperature factor of the inner surface.

Table.7: Results of temperature factor fRsi and comparison

Construction	θai	U	RsiT	θe	θai,min	fRsi	fRsi,N	Check
	[°C]	[W/m2.K]	[m2K/W]	[°C]	[°C]	[-]	[-]	
W1-Peripheral wall	20,6	0,09	0,25	-15	19,80	0,98	0,745	SATISFIED
F1-Floor	20,6	0,103	0,25	-15	19,68	0,97	0,745	SATISFIED
F5-Flat roof	20,6	0,07	0,25	-15	19,98	0,98	0,745	SATISFIED
Windows	20,6	1,10	0,25	-15	10,81	0,73	0,656	SATISFIED
Doors	20,6	0,85	0,25	-15	13,04	0,79	0,656	SATISFIED

The lowest internal surface temperature and the temperature factor of the inner surface in corners.

Calculation:

W1-F1

$\xi R_{si}=0,6(0,09*0,25)^{0.79} . (0,09/0,103)^{0,21}=0,029$

$fR_{si}=1- \xi R_{si}=1-0,029=0,971$

$\theta_{si,min}=\theta- \xi R_{si} . (\theta_{ai} - \theta_{e}) = 21-0,029 . (21- (-15) = 19,96$ °C

W1-F7

$\xi R_{si}=0,6(0,14*0,25)^{0.79} . (0,14/0,09)^{0,21}=0.046$

$fR_{si}=1- \xi R_{si}=1-0,046=0,954$

$\theta_{si,min}=\theta- \xi R_{si} . (\theta_{ai} - \theta_{e}) = 21-0,046 . (21- (-15) = 19,34$ °C

W1-W1

$\xi R_{si}=1,05.(U.R_{Sik})^{0.69} = 1,05 (0,09.0,25)^{0.69}= 0,0765$

$fR_{si}=1- \xi R_{si}=1-0,0765=0,923$

$\theta_{si,min}=\theta- \xi R_{si} . (\theta_{ai} - \theta_{e}) = 21-0,0765 . (21- (-15) = 18,25$ °C

W1-F5

ξR_{si}=0,6(0,07*0,25)$^{0.79}$. (0,07/0,09)^{0,21}=0.0232

fR_{si}=1- ξR_{si}=1-0,0232=0,9768

$\theta_{si,min}$=θ- ξR_{si} . (θ_{ai} - θ_e) = 21-0,0232 . (21- (-15) = 20,16 °C

Table.8: Results and comparison

Composition	θe [°C]	θi [°C]	U [W/m²·K]	θsim [°C]	ξRsi [-]
W1 F1	-15	20,6	0,09 0,103	19,96	0,029
W1 F7	-15	20,6	0,09 0,14	19,34	0,046
W1 W1	-15	20,6	0,09 0,09	18,25	0,0765
W1 F5	-15	20,6	0,09 0,07	20,16	0,0232

Table.9: Results and comparison

Construction	Calculated coef. U [W/m^2.K]	Required coef. UN,20 [W/m^2.K]	Check
W1-Peripheral wall	0,09	0,3	SATISFIED
F1-Floor	0,103	0,24	SATISFIED
F5-Flat roof	0,07	0,24	SATISFIED
Windows	1,10	1,5	SATISFIED
Doors	0,85	1,5	SATISFIED

8. Final evaluation

Protocol to the Energy Label of the Building Envelope

a. Identification data

Type of building	Family house
Address	Sadová 333
Cadaster region	Sadová [611565]
Owner	

b. Characteristics of the object

Characteristics of structures bordering the building envelope

Cooled structure	θai				
	Area A [m2]	Heat transfer coef. Ui [W . m-2.K-1]	Required heat transfer coef. UN,20 [W . m-2.K-1]	Thermal reduction factor bi [-]	Heat loss by heat transfer HTi = Ai.Ui.bi [W/mK]
W1-Peripheral wall	236,67	0,090	0,30	1,00	21,30
F1-Floor	111,60	0,103	0,24	0,43	4,94
F5-Flat roof	132,86	0,070	0,24	1,00	9,30
W/01 2 Pcs	11,52	0,78	1,5	1,00	8,99
W/02 3 Pcs	3,15	0,94	1,5	1,00	2,96
W/03	0,30	1,10	1,5	1,00	0,33
W/04	0,54	1,02	1,5	1,00	0,55
W/05 2 Pcs	5,68	0,82	1,5	1,00	4,66
W/06	11,25	0,70	1,5	100	7,88
W/07 2 Pcs	12,00	0,78	1,5	1,00	9,36
W/08	6,00	0,78	1,5	1,00	4,68
D/08	3,63	0,85	1,5	1,00	3,09
D/07	5,76	0,73	1,5	1,00	4,20
Sum	540,96				82,23
Thermal bridges	540,96 x 0,02				10,82
Total specific loss of heat transfer	93,05/540,96=0,17			Total	93,05

The structure fulfills the requirements according to ČSN 730540-2

c. Evaluation of the envelopes heat transfer

Average heat transfer coef. Uem = Ht/A	W/m².K	0,17
Required heat transfer coef. Uem,N	W/m².K	0,46

d. Classification classes of heat transfer through the building envelope

Construction	θai				θai,min			
	Area A [m²]	U [W/m².K]	b [-]	HT [W/mK]	Area A [m²]	U [W/m².K]	b [-]	HT [W/mK]
W1-Peripheral wall	236,67	0,30	1,00	71,00	236,67	0,090	1,00	21,30
F1-Floor	111,60	0,24	0,43	11,52	111,60	0,103	0,43	4,94
F5-Flat roof	132,86	0,24	1,00	31,89	132,86	0,070	1,00	9,30
W/01 2 Pcs	11,52	1,50	1,00	17,28	11,52	0,780	1,00	8,99
W/02 3 Pcs	3,15	1,50	1,00	4,73	3,15	0,940	1,00	2,96
W/03	0,30	1,50	1,00	0,45	0,30	1,100	1,00	0,33
W/04	0,54	1,50	1.00	0,81	0,54	1,020	1,00	0,55
W/05 2 Pcs	5,68	1,50	1.00	8,52	5,68	0,820	1,00	4,66
W/06	11,25	1,50	1.00	16,88	11,25	0,700	1.00	7,88
W/07 2 Pcs	12,00	1,50	1.00	18,00	12,00	0,780	1,00	9,36
W/08	6.00	1,50	1,00	9,00	6,00	0,780	1,00	4,68
D/08	3.63	1,50	1,00	5,45	3,63	0,850	1,00	3,09
D/07	5.76	1,50	1,00	8,64	5,76	0,730	1,00	4,20
Sum	540,96			204,15	540,96			82,23
Thermal bridges	540,96 x 0,02			10,82	540,96 x 0,02			10,82
Total specific loss of heat transfer	214,97/540,96			214,97	93,05/540,96			93,05
Average specific loss of the heat transfer Umr,rq	Uem,req		0,39		Uem		0,17	
Classification class of building envelope	0,17/0,39=0,43 Class B							

Classification classes	Average heat transfer coef. Uem [W/(m².K)]	Value
A-B	0,3 . $U_{em, rq}$	0,14
B-C	0,6 . $U_{em, rq}$	0,28
(C1-C2)	(0,75 . $U_{em, rq}$)	(0,35)
C-D	$U_{em, rq}$	0,46
D-E	0,5 . ($U_{em, rq}$ + $U_{em,s}$)	0,76
E-F	$U_{em,s}$ = $U_{em, rq}$ + 0,6	1,06
F-G	1,5 . $U_{em, s}$	1,60

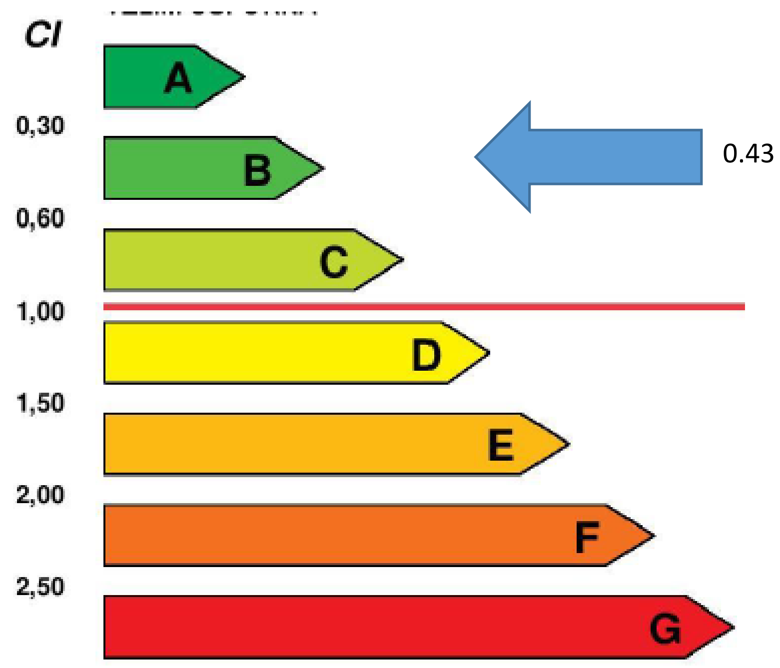
Classification:	B
Date of the issue of the classification:	20 / 05 / 2016
Maker of the classification:	David Lenďák
Address:	Helcmanovce 101, Slovakia
IČO:	
Elaborated:	David Lenďák

Signature:..

This protocol and energy label are in conformity with Directive 93/76/EWG of 13 September 1993, which was issued by the EU in the SAVE framework. It has been developed in accordance with ČSN 73 0540 and is delivered by the client according to the project documentation.

e. Energy label

LABEL OF BUILDING ENVELOPE							
Type:	Family House				Evaluation		
Address:	612 00 Brno-Královo Pole						
Total area:	223,2 m²				present	recommended	



CLASIFICATION					B		
Average loss by heat transfer Uem,N ve W/(m2.K) Uem = HT/A					0,17		
Required average loss by heat transfer of building envelope according the standard ČSN 73 0540-2 Uem,N ve W/(m2.K)					0,46		
Classification factor CI and its corresponding values							
CI	0,30	0,60	0,75	1,00	1,5	2,0	2,5
U_{em}	0,14	0,28	0,35	0,46	0,76	1,06	1,6
Expiration date:		Date: 05/2030					
Elaborated by:		Name and surname David Lenďák					

9. Assessment in terms of day lighting

In the vicinity of the parcel, there is no object that would obstruct the day lighting of the family house.

Own calculation