BRNO UNIVERSITY OF TECHNOLOGY

VYSOKÉ UČENÍ TECHNICKÉ V BRNĚ

FACULTY OF CIVIL ENGINEERING

FAKULTA STAVEBNÍ

INSTITUTE OF BUILDING STRUCTURES

ÚSTAV POZEMNÍHO STAVITELSTVÍ

APARTMENT BUILDING

BYTOVÝ DŮM

BUILDING PHYSICS REPORT

BACHELOR'S THESIS

BAKALÁŘSKÁ PRÁCE

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VEDOUCÍ PRÁCE

BRNO 2023

1- General information about the construction

Name:	Residential Building
Parcel no:	5049/24
Cadastral area:	LISEN
City:	BRNO
District:	Brno-Město
Region:	Jihomoravskı Kraj
State:	Czech Republic

The proposed design entails a residential building comprising four above-ground floors and one basement floor, intended to accommodate 24 individuals. In plan, the residential house takes on a semi-rectangular shape, with the entrance situated in the nortwestern part. Each flat above the first floor will feature a balcony, and the roof will be designed as a flat structure.

For the construction of the peripheral walls, KALKSANDSTEIN lime-sand blocks will be utilized in the above-ground storeys, while the basement will be constructed using site cast reinforced concrete. Similarly, the internal load-bearing walls will be constructed using KALKSANDSTEIN lime-sand blocks in the above-ground storeys, while the basement will incorporate site cast reinforced concrete. As for non-load-bearing walls, KALKSANDSTEIN lime-sand blocks with a rating of 4 will be utilized, alongside site cast reinforced concrete for the basement.

To ensure adequate insulation, the facade of the building will be equipped with an External Thermal Insulation Composite System (ETICS), incorporating Expanded Polystyrene (EPS) as the insulating material.

This proposed residential building design encompasses four above-ground floors and one basement, providing space for 24 occupants. Its semi-rectangular shape in plan is complemented by an entrance positioned in the southeastern section. Notably, each floor above the first will boast a balcony, while the roof will take a flat design.

The construction materials chosen for different elements of the building vary accordingly. KALKSANDSTEIN lime-sand blocks will be employed for the above-ground storeys' peripheral and load-bearing walls, while the basement will incorporate site cast reinforced concrete. Additionally, KALKSANDSTEIN lime-sand blocks will form the non-load-bearing walls, supplemented by site cast reinforced concrete for the basement.

To optimize insulation, an External Thermal Insulation Composite System (ETICS) will be implemented on the facade. This system integrates Expanded Polystyrene (EPS) as the insulating material, enhancing energy efficiency and comfort within the residential building.

2- Purpose of Assessment

The assessment aims to ascertain compliance with specific criteria outlined in Decree No. 268/2009 Coll., which pertains to technical requirements for construction. This decree, amended by Decree No. 20/2012, outlines the following aspects that need to be verified:

1. Thermal-technical requirements: The assessment ensures that the structure and its construction meet the necessary standards for thermal performance, including insulation and energy efficiency.
2. Energy-saving requirements: The evaluation examines whether the object fulfills the prescribed energy-saving requirements, ensuring optimal energy usage and sustainability.
3. Soundproofing properties of structures: The assessment checks if the construction adequately addresses soundproofing measures to minimize the transmission of noise and ensure acoustic comfort within the building.
4. Requirements for spatial acoustics: This aspect assesses whether the spatial acoustics within the building meet the specified criteria, ensuring suitable sound quality and intelligibility in different areas and rooms.
5. Requirements for sunlight: The evaluation examines whether the design and construction of the structure incorporate provisions for optimal natural lighting, considering factors such as daylight availability and distribution.

Furthermore, the assessment is conducted to safeguard the safety and hygiene of the structure, as well as to verify the proper functioning of the object. By ensuring compliance with the prescribed standards and regulations, the assessment aims to create a secure and healthy environment while maintaining the intended functionality of the building.

3- Material used for eleboration

-Study of bachelor project
-Catalogue information for the used materials
-Climatic conditions on site
-Boundary indoor and outdoor conditions

4- Used regulations and standards

[1] Zákon č. 183/2006 Sb. o územním plánování a stavebním řádu (stavební zákon) ve znění pozdějších předpisů;
[2] Zákon č. 406/2000 Sb. o hospodaření energií ve znění pozdějších předpisů;
[3] Vyhláška č. 268/2009 Sb., o technických požadavcích na stavby ve znění vyhlášky č. 20/2012 Sb.;
[4] Vyhláška č. 499/2006 Sb., o dokumentaci staveb ve znění pozdějších předpisů;
[5] Vyhláška č. 78/2013 Sb. o energetické náročnosti budov;
[6] Nařízení vlády č. 272/2011 Sb., o ochraně zdraví před nepříznivými účinky hluku a vibrací;
[7] Nařízení vlády č. 361/2007 Sb., kterým se stanoví podmínky ochrany zdraví při práci ve znění pozdějších předpisů;
[8] ČSN 730540-1:2005 Tepelná ochrana budov-Část 1: Terminologie;
[9] ČSN 730540-2:2011 + Z1:2012 Tepelná ochrana budov – Část 2: Požadavky;
[10] ČSN 730540-3:2005 Tepelná ochrana budov – Část 3: Návrhové hodnoty veličin;
[11] ČSN 730540-4:2005 Tepelná ochrana budov – Část 4: Výpočtové metody;
[12] ČSN 730532:2010 Akustika – Ochrana proti hluku v budovách a posuzování akustických vlastností stavebních výrobků – Požadavky;
[13] ČSN 730525 - Akustika – Projektování v oboru prostorové akustiky – Všeobecné zásady.
[14] ČSN 73 4301:2004 + Z1:2005 + Z2/2009 Obytné budovy;
[15] ČSN 73 0580-1:2007 + Z1:2011Denní osvětlení budov – část 1: Základní požadavky;
[16] ČSN 73 0581:2009 Oslunění budov a venkovních prostor – Metoda stanovení hodnot.

5- Assessment from the spectre of energy saving and heat protection

5.1- Normative Requirements

Minimum internal surface temperature of the structure

The lowest internal surface temperature is expressed by the temperature factor of the inner surface

fRsi,

$f_{Rsi} = (\theta_{si} - \theta_e) / (\theta_{ai} - \theta_e)$
$\theta_{si} = \theta_{ai} - U * R_{siT} * (\theta_{ai} - \theta_e)$

where:
θ_{si} -internal surface temperature [°C]
θ_e -design temperature of the exterior air in winter [°C]
θ_{ai} -design temperature of the interior air [°C]
U -heat transfer coefficient of the structure [W/m2.K]
R_{siT} -thermal resistance [m2.K/W]

The requirement of lowest internal surface temperature is defined by the following condition:

$f_{Rsi} \geq f_{Rsi,N}$

-*fRsi,N* is the required value of the lowest temperature factor of the inner surface

θ_{ai} = 20,6 °C → f_{RsiN} = 0,747

Heat transfer coefficient

The requirements for the heat transfer coefficient for the building structures are expressed in the condition : $U \leq U_N$

Type	**UN,20**	**Urec,20**	**Upas,20**	**UNzeb,20= 0,7xUN,20**
External wall	0,3	0,25	0,18-0,12	0,21
Tempered space floor/wall to soil	0,85	0,60	0,45-0,30	0,595
Floor above tempered space	0,75	0,50	0,38-0,25	0,315
Flat roof	0,24	0,16	0,15-0,10	0,168
Windows	1,5	1,2	0,8-0,6	1,05
Doors	1,7	1,2	0,9	1,19

$U_{N,20}$ – required U-value [W/m2.K]
$U_{rec,20}$ – recommended U-value [W/m2.K]
$U_{pas,20}$ – U-value for passive buildings [W/m2.K]
$U_{NZEB,20}$ – U-value for passive buildings [W/m2.K]

Average heat transfer coefficient

The requirements for the average heat transfer coefficient for the building structures is expressed in the condition :

$U_{em} \leq U_{emN}$

where:
U_{em} -average heat transfer coefficient of the structure [W/m2.K]
U_{emN} -required average heat transfer coefficient of the structure [W/m2.K]

Required average heat transfer coefficient of the structure U_{emN} is obtained from the calculation of reference building. Reference building is the a building with same spatial and dimensional properties as the examined buildings, with all the U-values being of a UN,20. For all the new residential buildings $U_{em,N} \leq 0{,}5$ [W/m2.K]

Linear and point heat transfer factor

The requirements for the linear and point heat transfer factor for the building structures are expressed in the condition :

$\Psi \leq \Psi N$
$\chi \leq \chi N$

where:
Ψ_N -required linear heat transfer factor
χ_N -required point heat transfer factor

Linear	**ΨN**	**Ψrec**	**Ψpas**
Wall connected to other construction	0,20	0,10	0,05
Wall connected to filling of the opening	0,10	0,03	0,01
Roof connected to filling of the opening	0,30	0,1	0,02
Point	**χN**	**χrec**	**χpas**
Windows	0,4	0,1	0,02

Drop of floor contact temperature

Floors in the rooms are classified to several categories upon fulfilling the following condition:
$\Delta\theta_{10} \leq \Delta\theta_{10,N}$

where:

$\Delta\theta_{10,N}$ -required value for contact temperature drop [°C] **Category of floor**	**$\Delta\theta_{10,N}$**
I I. Very warm	≤ 3,8
I II. Warm	≤ 5,5
I III. Less warm	≤ 6,9
I IV. Cold	6,9 <

Requirements for the residential buildings:

Type of the room	**Required Category of floor**
bedroom	I.
living room, office, kitchen	II.
bathroom, WC	III.
entrance hall	IV.

Condensed water vapour inside the structure

The limiting amount of water vapour inside the structure, for the building where water vapour doesn't endanger its function, is expressed by the condition

$M_c \leq M_{c,N}$

where:
Mc -annual amount of condensed water vapour inside the structure [kg/m2.a]
Mc, N -allowable amount of condensed water vapour inside the structure [kg/m2.a]

Mc, N = 0,1 kg/m2.a or 3% of the weight of material, where condensation appears, if $\rho > 100$ kg/m3 (for $\rho \leq 100$ kg/m3 , 6% is used)

Annual balance of condensation and evaporation of water vapour

The annual amount of condensed water vapour in structure is limited by the condition:
$M_{c,a} \leq M_{ev,a}$

where:
Mc is the annual amount of condensed water vapour inside the structure
Mev is the annual volume of evaporated water vapour inside the structure

Thermal stability of room in winter

The of thermal stability of the room in winter is acquired by fulfilling the following condition
$\Delta\theta_v(t) \leq \Delta\theta_{v,N}(t)$

where:
$\Delta\theta_v(t)$ -decrease of room temperature in winter [°C]
$\Delta\theta_{v,N}(t)$ -maximal value for decrease of room temperature in winter [°C]

Type of room	$\Delta\theta_{v,N}(t)$
People stay after heating is interrupted:	
-heating radiators, radiant panels, hot air	3
-stove heating, underfloor heating	4

No people stay after heating is interrupted:
-heating interrupted due to heating break:

-massive building	6
-light building	8
-at the prescribed lowest temperature $\theta v,min$	$\theta i- \theta r,min$
-storing food	$\theta i-8$
-risk of freezing water	$\theta i-1$

Thermal stability of room in summer

The of thermal stability of the room in summer is acquired by fulfilling the following condition:

$\theta ai,max \leq \theta ai,max,N$

where:

$\theta ai,max$ -highest daily temperature of room in summer [°C]
$\theta ai,max,N$ -maximal highest daily temperature of room in summer [°C]

$\theta ai,max,N = 27.0°C$ for the non-production buildings.

5.2 Technical information about the building from the spectre of energy saving and heat protection

Geometrical characteristics of the building

The proposed residential building features a semi-rectangular plan, consisting of four above-ground floors and one basement level. It boasts a flat roof design, while the entrance is thoughtfully positioned in the nortwest direction. Notably, the building stands independently, detached from neighboring structures within its location.

Characteristics of the examined structures

A) Floor above basement

Material	**d [m]**	**λ [W/m.K]**
Ceramic tiles	0,008	1
Cement adhesive	0,005	1,4
Hydro insulation paint	-	-
Penetration layer	-	-
Anhydrite screed	0,055	1,25
PE separation layer	-	-
ISOVER EPS Neofloor 150	0,08	0,031
RC Slab	0,150	1,43
Cement based adhesive layer	0,005	1,4
ISOVER EPS Neofloor 150	0,8	0,031
PE Sieve reinforcement	-	-
Cement based adhesive layer	0,005	1,4
Plaster	0,1	0,99

Material	**d [m]**	**λ [W/m.K]**
Laminate floor	0,01	0,22
Damping Pad Mirelon Foam Polyethylen	0,003	0,05
Anhydrite screed	0,055	1,25
PE separation layer	-	-
ISOVER EPS Neofloor 150	0,08	0,031
RC Slab	0,150	1,43
Cement based adhesive layer	0,005	1,4
ISOVER EPS Neofloor 150	0,8	0,031
PE Sieve reinforcement	-	-
Cement based adhesive layer	0,005	1,4
Plaster	0,1	0,99

B) Basement floor above soil

Material	d [m]	λ [W/m.K]
Ceramic tiles	0,008	1
Cement adhesive	0,005	1,4
Hydro insulation paint	-	-
Penetration layer	-	-
Anhydrite screed	0,055	1,25
PE separation layer	-	-
ISOVER EPS Neofloor 150	0,080	0,031
Hydro-insulation asphalt layer	0,004	0,21
Asphalt penetration layer	-	-
RC foundation Slab	0,4	1,43
Concrete base layer	0,1	1,25

C) External wall

Material	d [m]	λ [W/m.K]
External thin silicate render	0,002	0,12
Penetration in colour of render	-	-
PE sieve reinforcement	-	-
Cement based adhesive layer	0,005	1,4
ISOVER EPS GreyWall Plus	0,200	0,031
Cement based adhesive layer	0,005	1,4
KS 8DF E24/LP lime-sand block	0,24	0,99
Adhesive layer	-	-
Internal plaster	0,015	0,86

D) Basement wall adjacent to soil

Material	d [m]	λ [W/m.K]
Studded membrane	0,008	0,2
ISOVER EPS perimeter	0,100	0,033
Hydro-insulation asphalt layer	-	-
RC monolithic wall	0,240	1,43
Penetration layer	-	-
Internal plaster	0,01	0,86

E) Flat roof

Material	d [m]	λ [W/m.K]
Gravel	0,140	0,93
Filtration layer geotextile	-	-
Hydro insulation PVC-P foil	0,0015	0,16
Geotextile separation layer	-	-
ISOVER NEOFLOOR 150 EPS	0,160	0,031
ISOVER STYRODUR EPS	0,040	0,034
Vapour-insulation asphalt layer	0,002	0,21
Asphalt penetration layer	-	-
RC Slab	0,150	1,43
Adhesive layer	-	-
Internal plasterboard	0,01	0,19

F) Windows and balcony doors

VEKRA NATURA 94
-timber frame
-triple glazing Ug=0,5 W /m2.K
-Uw=0,7 W /m2.K

D) Doors

Entrance doors:
VEKRA trend 94
-timber frame
-triple glazing Ug=0,5 W /m2.K
-Ud=0,82 W /m2

5.3 Information about compliance with normative requirements

Assessment of the lowest internal surface temperature

Structure	θai [°C]	θe [°C]	RsiT [m2.K/W]	U [W/m2.K]	fRsi	fRsi,N	Note
Floor above the soil C14	20,6	-15	0,25	0,312	0,924	0,747	Satisfied
Floor above the basement C12				0,171	0,958	0,747	Satisfied
External wall C1				0,144	0,965	0,747	Satisfied
Basement wall Adjacent to soil C2				0,295	0,929	0,747	Satisfied
Flat roof C16				0,147	0,964	0,747	Satisfied
Windows				0,7	0,825	0,697	Satisfied
Doors				0,82	0,795	0,697	Satisfied

The designed structures meet the minimal requirements for the lowest internal surface temperature.

Assessment of heat transfer coefficient

Type	UN,20	Urec,20	Upas,20	UNzeb,20	U	Note
External wall -C1	0,3	0,25	0,18-0,12	0,21	0,144	Satisfied
Tempered space floor to soil -C14	0,85	0,60	0,45-0,30	0,595	0,312	Satisfied
Tempered space wall to soil -C2	0,85	0,60	0,45-0,30	0,595	0,295	Satisfied
Floor above tempered space -C12	0,75	0,50	0,38-0,25	0,315	0,171	Satisfied
Flat roof -C16	0,24	0,16	0,15-0,10	0,168	0,147	Satisfied
Windows	1,5	1,2	0,8-0,6	1,05	0,7	Satisfied
Doors	1,7	1,2	0,9	1,19	0,82	Satisfied

The designed structures meet the requirements for heat transfer coefficient and fulfils the required values for NZEB,20.

Diffiusion of water vapour in structures

Structure	Mc,a [kg/(m2.a)]	Mev,a [kg/(m2.a)]	Note
Basement floor above soil – C14	0,233	0,241	Satisfied
Flat roof -C16	0,0019	0,0060	Satisfied
External wall – C1	0.001	1.45	Satisfied

The designed structures meet the requirements for the annual amount of condensed water vapour in structure.

Evaluation of building envelope

Structure	Reference Building				Evaluated building			
	Ai [m2]	U [W/(m2.K)]	bi	Specific loss of heat transfer HT [W/(m2.K)]	Ai [m2]	U [W/(m2.K)]	bi	Specific loss of heat transfer HT [W/(m2.K)]
Basement floor	214,36	0,85	0,30	54.66	214,36	0,30	0,30	19.29
External wall	908,42	0,30	1,00	272.52	908.42	0,14	1,00	127.17
Basement wall	235,29	0,85	0,30	59.99	235.29	0,29	0,30	20.47
Flat Roof	214,36	0,24	1,00	51.44	214,36	0,14	1,00	30.01
Windows	84.44	1,50	1,00	126.66	84.44	0,7	1,00	59.10
Doors	20.2	1.7	1,00	34.34	20.2	0,8	1,00	16.16
Total	A=1677.07			599.61	1677.07			272.2
Thermal bridges	1677.07x0,02			33.54	1677.07x0,02			33.54
Total HT				633.15				305.74
Average HT	Uem,req= 0,377				Uem= 0,182			
Class	Uem,req/2= 0,188				CLASS A			

Classification class	Average heat transfer coef. Uem [W/(m2.K)]	Verbal statement
A	Uem ≤ 0,5.Uem,req	Very efficient
B	0,5.Uem,req < Uem ≤ 0,75.Uem,req	Efficient
C	0,75.Uem,req < Uem ≤ Uem,req	Approvable
D	Uem,req < Uem ≤ 1,5.Uem,req	Not Approvable
E	1,5.Uem,req < Uem≤ 2.Uem,req	Not Efficient
F	2.Uem,req < Uem ≤ 2,5.Uem,req	Inefficient
G	2,5.Uem,req < Uem	Unusually inefficient

The building envelope has an average heat transfer coefficient Uem=0,182 W/(m2.K), which fulfils the requirement Uem=0,182 W/(m2.K) < Uem,req/2=0,188 W/(m2.K). The building was evaluated with the classification class A-very efficient. Building fullfills the requirement for NZEB.

6- Assessment from the aspect of acoustics and vibration

6.1 Normative requirements

Airborne sound insulation

Evaluated structures must fulfil the following requirement for the airborne sound insulation :

Rw´>Rw,N
Rw´: Rw-k1

where:

Rw… weighted laboratory sound insulation [dB]
k_1 …correction [dB]
Rw´ … weighted construction sound insulation [dB]
$R_{w,N}$… the standard value of the weighted building noise sound insulation [dB]

Required values for residential buildings:

Structure	**Rw,N**
Wall	52dB
Slab	52dB
Doors	32dB

Impact sound insulation

Evaluated structures must fulfil the following requirement for the impact sound insulation
$L'_{n,w} \leq L'_{n,w,n}$
$L'_{n,w} = L_{n,w} + k_2$

where:
$L_{n,w}$ … value for normalised sound pressure level [dB]
k_2 …correction [dB]
L_{nw}' … weighted value for normalised sound pressure level [dB]

$L_{nw,n}$… the standard value for normalised sound pressure level [dB]

Structure	**Lnw,n**
Slab	52dB

Characteristics of the examined structures

Floors:

A)

Material	d [m]
Ceramic tiles	0,008
Cement adhesive	0,005
Hydro insulation paint	-
Penetration layer	-
Anhydrite screed	0,055
PE separation layer	-
ISOVER EPS Neofloor 150	0,08
RC Slab	0,150
False ceiling installation cavity	0,3
Steel grate supporting structure	2x0,025
Plasterboard	0,15

B)

Material	d [m]
Laminate floor	0,01
Damping pad mirelon foam polyethylen 3mm	0,002
Anhydrite screed	0,055
PE separation layer	-
ISOVER EPS Neofloor 150	0,08
RC Slab	0,150
False ceiling installation cavity	0,3
Steel grate supporting structure	2x0,025
Plasterboard	0,15

Walls

Internal load bearing:

Material	d [m]
Plaster	0,01
Penetration layer	-
KS 10DF E30/LP lime-sand block	0,3
Penetration layer	-
Plaster	0,01

Partitions:

Material	d [m]
Plaster	0,01
Penetration layer	-
KS 15DF E15LP lime-sand block	0,15
Penetration layer	-
Plaster	0,01

6.2 Information about compliance with normative requirement

Airborne sound insulation

Structure	$R_{w,N}$ [dB]	Rw´[dB]	note
Slab between flats -ceramic tiles	53	58,5	Satisfied
Slab between flats – laminate flooring	53	58,5	Satisfied
Wall to common areas	53	63	Satisfied
Wall to technical room	57	63	Satisfied
Partitions in flat	42	48	Satisfied
Doors	32	44	Satisfied

All the evaluated structures fulfil the requirements for the acoustic airborne sound insulation.

Impact sound insulation

Structure	$L_{nw,n}$ [dB]	**Lnw´ [dB]**	**note**
Slab between flats - ceramic tiles	53	40,91	Satisfied
Slab between flats – laminate flooring	53	40,91	Satisfied

All the evaluated structures fulfil the requirements for the acoustic impact sound insulation.

7.1 Regulations and requirements

7.1.1 Regulations for daylighting in living rooms

Requirements in accordance with ČSN 73 0580 - 2: 2007 for all living rooms with side lighting:

• Two assessment points in the middle of the room are set, depth (maximum 3 m from the window wall) at a distance of 1 m from the side walls, the value of the daylight factor must be greater than or equal to 0.7%

• At the same time, the average value of the daylight factor determined from these two assessment points must be at least 0.9%.

7.1.2 Specific sun exposure value for residential buildings and its areas

All apartments and residential units must take into account layout design for minimal sun exposure value in order to meet the required limits. An apartment is sufficiently illuminated if the floor area sum of sunny living rooms is equal to at least one third of the total living room floor area.
Floor area sum of the illuminated living rooms and the total sum of the living room floor areas of the apartment for this purpose do not include parts that lie beyond the room depth of 2.3 times its clear room height.

A living room is considered well illuminated if the following requirements are met:

• The layout angle of the sun's rays by the main line of the plane of the window opening must be at least 25°, the main line of the plane is the line that is the intersection of this plane with the horizontal plane.

• Direct sunlight must enter the room for a specified period of time through a window opening or openings covered with a transparent and non-distorting material, the total area of openings is at least one tenth of the floor area of the room; the smallest composite dimension of the lighting opening must be at least 900 mm; the width of slope roof windows may be less, but at least 700 mm.

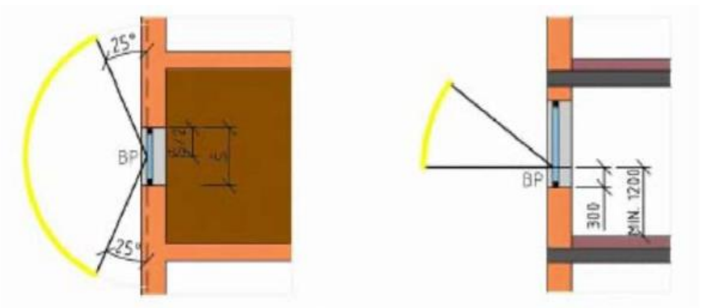
• Sunlight must fall for a specified time at a critical point within the plane of the internal glazing at a height of 300 mm above the centre of the lower edge of the lighting opening, but at least 1200 mm above the floor level of the assessed room.

• The height of the sun above the horizon must be at least 5 °.

• If the clouds are neglected, the sun exposure value forMarch 1st and June 21th must be at least 90 minutes.

The required sunshine period for 1 March may be replaced by a balance sheet in which, except for the leap years, the total sunshine values are from February 10th toMarch 21st equal to 3600 minutes (40 days with an average sun exposure of 90 minutes).

When designing residential buildings, shading is taken into account not only according to the current state of the surroundings but covers also the possibility of later urban changes according to the zoning decision and the urban plan, if approved for the area. A uniform average northern latitude φ = 50 ° is used to assess the time of sun exposure.



Picture 1: Requirements for sun exposure in accordance with ČSN 73 4301

The building met with the requirements.

8. Conclusion

The residential building has been designed to meet the prescribed standards for acoustics, energy efficiency, heat protection, and daylighting. It successfully meets the criteria for a Nearly Zero Energy Building (NZEB) with regards to evaluating the building envelope and heat transfer coefficients.

9. Annex

The annex contains evaluations and calculations related to building physics. These calculations include the utilization of TEPLO 2017 EDU software, which provides outputs for examining energy savings and heat protection aspect.