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BUILDING PHYSICS

APEX 1: CALCULATION PART

BAKALÁŘSKÁ PRÁCE
BACHELOR ´S THESIS

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1) W1- PERIPHERAL WALL

a) CALCULATION OF THERMAL RESISTANCE OF THE CONSTRUCTION

$R_j = d_j / \lambda_j$

where R_j.....thermal resistance of j- layer [m^2.K/W]
d_j.....thickness of j- layer of construction [m]
λ_j....design value of coefficient of thermal conductivity of material [W/m.K]

W1
PERIPHERAL WALL

N.L.	MATERIAL	d [m]	λ [W/m.K]	R [m2.K/W]
1	LIME CEMENT PLASTER SAKRET PM, TH. 10mm	0,01	0,88	0,01
2	LOAD BEARING BRICKS HELUZ FAMILY CUT, TH. 250mm	0,25	0,14	1,79
3	ISOVER TOPSIL 8 MINERAL WOOL	0,16	0,038	4,21
4	VAPOUR DIFFUSIVE FOIL PK-FOL MP	0,002	-	-
5	TIMBER FRAME, LATHS 40X60 mm	0,04	-	-
6	WOODEN DECKING THERMWOOD UYL 20X140 mm	0,019	-	-
			∑R=	**6,00**

b) CALCULATION OF THERMAL RESISTANCE OF CONSTRUCTION WITHIN THE HEAT TRANSFER

$R_T = R_{SI} + \sum R + 2 R_{SE} = 0{,}13 + 6{,}00 + 2x0{,}04 = 6{,}21$ m^2.K/W

where R_T...total thermal resistance of construction [m^2.K/W]
R_{SI}...thermal resistance within the heat transfer at the interior side [m^2.K/W]
$\sum R$...sum of thermal resistances of individual layers of construction [m^2.K/W]
R_{SE}... thermal resistance within the heat transfer at the exterior side [m^2.K/W]

c) CALCULATION OF HEAT TRANSFER COEFFICIENT

$U = 1/ R_T = 1/6{,}21 = 0{,}16$ W/m^2.K

where U...coefficient of heat transfer [W/m^2.K]
R_T...total thermal resistance of construction [m^2.K/W]

d) REGARDING THE POINT THERMAL BRIDGES THE ADDITIONAL Δ U [W/m^2.K]

Δ U = 0,02 W/m^2.K

e) CALCULATION OF TOTAL HEAT TRANSFER COEFFICIENT
U= U_i+ Δ U
U=0,16 + 0,02= **0,18** W/m^2.K

2) F1- FLOOR IN THE GROUND FLOOR 1 - UNHYDRITE WITH LAMINATE FLOOR

a) CALCULATION OF THERMAL RESISTANCE OF THE CONSTRUCTION

$R_j = d_j / \lambda_j$

where R_j.....thermal resistance of j- layer [m^2.K/W]
d_j.....thickness of j- layer of construction [m]
λ_j....design value of coefficient of thermal conductivity of material [W/m.K]

N.L.	**MATERIAL**	**d [m]**	**λ [W/m.K]**	**R [m2.K/W]**
1	FLOATING LAMINATE FLOOR PARADOR	0,007	0,3	0,02
2	MIRELON	0,002	0,046	0,04
3	AFE 20 ANHYDRITE SCREED SAKRET	0,04	1,1	0,04
4	SEPARATION PE FOIL / SAKRET	0,002	-	-
5	Isover EPS 100S	0,16	0,037	4,32
6	ELASTOBIT GG 40	0,004	0,21	-
7	REINFORCED CONCRETE SLAB	0,15	-	-
8	GRAVEL SUB BASE	0,2	-	-
9	ORIGINAL SOIL	-	-	-
			∑R=	**4,42**

b) CALCULATION OF THERMAL RESISTANCE OF CONSTRUCTION WITHIN THE HEAT TRANSFER

$R_T = R_{SI} + \sum R + R_{SE}$ = 0,17+ 4,42+0,00 = 4,59 m^2.K/W

where R_T...total thermal resistance of construction [m^2.K/W]
R_{SI}...thermal resistance within the heat transfer at the interior side [m^2.K/W]
∑ R...sum of thermal resistances of individual layers of construction [m^2.K/W]
R_{SE}... thermal resistance within the heat transfer at the exterior side [m^2.K/W]

c) CALCULATION OF HEAT TRANSFER COEFFICIENT

U = 1/ R_T = 1/4,59 = 0,218 W/m^2.K

where U...coefficient of heat transfer [W/m^2.K]
R_T...total thermal resistance of construction [m^2.K/W]

d) REGARDING THE OPTIMALISED THERMAL BRIDGES THE ADDITIONAL Δ U [W/m^2.K]

Δ U = 0,02 W/m^2.K

e) CALCULATION OF TOTAL HEAT TRANSFER COEFFICIENT
U= U_i+ Δ U
U=0,218 + 0,02= **0,238** W/m^2.K

3) F2 FLOOR IN THE GROUND FLOOR 2- UNHYDRITE WITH CERAMIC TILES

a) CALCULATION OF THERMAL RESISTANCE OF THE CONSTRUCTION

$R_j = d_j / \lambda_j$

where R_j.....thermal resistance of j- layer [m^2.K/W]
d_j.....thickness of j- layer of construction [m]
λ_j....design value of coefficient of thermal conductivity of material [W/m.K]

N.L.	**MATERIAL**	**d [m]**	**λ [W/m.K]**	**R [m2.K/W]**
1	CERAMIC TILES RAKO STONE	0,008	1,01	0,01
2	CERAMIC TILES ADHESIVE C1T SAKRET	0,005	1,3	0,00
3	PENETRATION SAKRET A&H	-	-	-
4	AFE 20 ANHYDRITE SCREED SAKRET	0,04	1,1	0,04
5	SEPARATION PE FOIL / SAKRET	0,002	-	-
6	Isover EPS 100S	0,16	0,037	4,32
7	ELASTOBIT GG 40	0,004	0,21	-
8	REINFORCED CONCRETE SLAB	0,15	-	-
9	GRAVEL SUB BASE	0,2	-	-
10	ORIGINAL SOIL	-	-	-
			∑R=	**4,37**

b) CALCULATION OF THERMAL RESISTANCE OF CONSTRUCTION WITHIN THE HEAT TRANSFER

$R_T = R_{SI} + \sum R + R_{SE}$ = 0,17+ 4,37+0,00 = 4,54 m^2.K/W

where R_T...total thermal resistance of construction [m^2.K/W]
R_{SI}...thermal resistance within the heat transfer at the interior side [m^2.K/W]

$\sum$ R...sum of thermal resistances of individual layers of construction [m^2.K/W]
R_{SE}... thermal resistance within the heat transfer at the exterior side [m^2.K/W]

c) CALCULATION OF HEAT TRANSFER COEFFICIENT

$U = 1/ R_T = 1/4{,}54 = 0{,}222$ W/m^2.K

where U...coefficient of heat transfer [W/m^2.K]
R_T...total thermal resistance of construction [m^2.K/W]

d) REGARDING THE OPTIMALISED THERMAL BRIDGES THE ADDITIONAL Δ U [W/m^2.K]

$\Delta U = 0{,}02$ W/m^2.K

e) CALCULATION OF TOTAL HEAT TRANSFER COEFFICIENT
$U= U_i+ \Delta U$
U=0,222 + 0,02= **0,242** W/m^2.K

4) R1- CEILING INTO UNHEATED ATTIC

a) CALCULATION OF THERMAL RESISTANCE OF THE CONSTRUCTION

$R_j = d_j / \lambda_j$

where R_j.....thermal resistance of j- layer [m^2.K/W]
d_j.....thickness of j- layer of construction [m]
λ_j....design value of coefficient of thermal conductivity of material [W/m.K]

N.L.	**MATERIAL**	**d [m]**	**λ [W/m.K]**	**R [m2.K/W]**
1	GYPSUM BOARDS KNAUF 12,5 mm	0,0125	0,21	0,06
2	BLOWN CELLULOSE TEMPAL	0,1	0,0396	2,53
3	OSB BOARD 15 mm WITH SEALED CONNECTIONS	0,015	0,13	0,12
4A	THERMAL INSULATION BLOWN CELLULOSE TEMPLAN	0,1	0,0396	2,53
4B	LOWER CHORD OF THE TRUSS	0,1	0,18	0,56
5	THERMAL INSULATION BLOWN CELLULOSE TEMPLAN	0,1	0,0396	2,53
6	VAPOUR DIFFUSIVE FOIL PK-FOL MP	0,002	-	-

b) CALCULATION OF RESISTANCE PERPENDICULAR TO THE HEAT FLUX

$R_1= 0{,}06$ m^2.K/W

R_2= 2,53 m^2.K/W
R_3= 0,12 m^2.K/W

R_4:

λ_{EQ}=($\lambda_W A_W + \lambda_C A_C$) / ($A_W + A_C$)
λ_{EQ}=(0,18x0,008+0,0396x0,091) / (0,008+0,091)
λ_{EQ}= 0,051 W/m.K

A_W= 0,1 x 0,08 = 0,008 m^2
A_C = 0,1 x 0,91 = 0,091 m^2

R_4= d_4/ λ_{EQ}
R_4= 0,1/0,051= 1,96 m^2.K/W

R_5= 2,53 m^2.K/W

R_P= R_1+ R_2+ R_3+ R_4+ R_5
R_P= 0,06+2,53+0,12+1,96+2,53
R_P= 7,2 m^2.K/W

c) CALCULATION OF RESISTANCE PARALLEL TO THE HEAT FLUX

R_A= R_1+ R_2+ R_3+ R_{4A}+ R_5
R_A=0,06+2,53+0,12+2,53+2,53=7,77 m^2.K/W

R_B= R_1+ R_2+ R_3+ R_{4B}+ R_5
R_B=0,06+2,53+0,12+0,56+2,53= 5,8 m^2.K/W

R_{II}= A/ ($\sum A_J/R_J$)
R_{II}=0,990 x 0,3275 /((0,08x0,3275)/5,8)+(0,91x0,3275)/7,77)
R_{II}=0,324/(0,0045+0,038)
R_{II}=7,56 m^2.K/W

d) TOTAL RESISTANCE

R=1/3 x (R_{II}+2 R_P)
R=7,32 m^2.K/W

R_T= R_{SI} + $\sum$ R + R_{SE} = 0,1+ 7,32 +0,04 = 7,46 m^2.K/W

where R_T...total thermal resistance of construction [m^2.K/W]
R_{SI}...thermal resistance within the heat transfer at the interior side [m^2.K/W]
$\sum$ R...sum of thermal resistances of individual layers of construction [m^2.K/W]
R_{SE}... thermal resistance within the heat transfer at the exterior side [m^2.K/W]

e) CALCULATION OF HEAT TRANSFER COEFFICIENT

U = 1/ R_T = 1/7,46 = 0,134 W/m^2.K

where U...coefficient of heat transfer [$W/m^2.K$]

R_T...total thermal resistance of construction [$m^2.K/W$]

CRITERION

R_{II}- R_P/ $R_P \leq 0{,}25$

$0{,}05 \leq 0{,}25$ FULLFILLED

f) REGARDING THE OPTIMALISED THERMAL BRIDGES THE ADDITIONAL Δ U [$W/m^2.K$]

$\Delta U = 0{,}02\ W/m^2.K$

g) CALCULATION OF TOTAL HEAT TRANSFER COEFFICIENT

$U= U_i+ \Delta U$

$U=0{,}134 + 0{,}02= 0{,}154\ W/m^2.K$

1.2 CALCULATION OF LOWEST SURFACE TEMPERATURE AND CRITICAL FACTOR FOR INDIVIDUAL CONSTRUCTIONS

Initial conditions:

- design inner temperature in winter season : $\theta_i = 20$ °C
- corrected design inner temperature: $\theta_{a,i}= \theta_i + \Delta \theta_{a,i}$

  $\theta_{a,i}= 20 + 0{,}6 = 20{,}6$ °C - rounded to 21 °C - safe side
- relative humidity of internal air: $\phi = 50$ %
- design external temperature in winter: $\theta_e = -15$ °C
- values of U [$W/m^2.K$] are recalculated for $R_{si}= 0{,}25\ m^2.K/W$

1) W1- PERIPHERAL WALL

a) THE LOWEST SURFACE TEMPERATURE

$$\theta_{si,min} = \theta_{a,i} - U \cdot R_{si} \cdot (\theta_{a,i} - \theta_e)$$

where $\theta_{si,min}$ [°C] .... lowest surface temperature

$\theta_{a,i}$...design interior temperature[°C]

U...coefficient of heat transfer [W/m^2.K]
R_{SI}...thermal resistance within the heat transfer at the interior side [m^2.K/W]
θ_e...design exterior temperature [°C]

$\theta_{si,min}$ =21- 0,18 . 0,13. (21- (-15))= 20,2 °C

b) CRITICAL FACTOR

$\mathbf{f_{Rsi} = (\theta_{si,min} - \theta_e) / (\theta_{ai} - \theta_e)}$

where f_{Rsi}.. critical factor of internal surface [-]
$\theta_{a,i}$...design interior temperature[°C]
U...coefficient of heat transfer [W/m^2.K]
R_{SI}...thermal resistance within the heat transfer at the interior side [m^2.K/W]
θ_e...design exterior temperature [°C]

f_{Rsi} = (20,2 - (-15)) / (21 - (-15)) = 0,978

2) R1- CEILING INTO UNHEATED ATTIC

a) THE LOWEST SURFACE TEMPERATURE

$\mathbf{\theta_{si,min} = \theta_{a,i} - U . R_{si} . (\theta_{a,i} - \theta_e)}$

where $\theta_{si,min}$ [°C] .... lowest surface temperature
$\theta_{a,i}$...design interior temperature[°C]
U...coefficient of heat transfer [W/m^2.K]
R_{SI}...thermal resistance within the heat transfer at the interior side [m^2.K/W]
θ_e...design exterior temperature [°C]

$\theta_{si,min}$ =21- 0,15 . 0,1. (21- (-15))= 20,46 °C

b) CRITICAL FACTOR

$\mathbf{f_{Rsi} = (\theta_{si,min} - \theta_e) / (\theta_{ai} - \theta_e)}$

where f_{Rsi}.. critical factor of internal surface [-]
$\theta_{a,i}$...design interior temperature[°C]
U...coefficient of heat transfer [W/m^2.K]

R_{SI}...thermal resistance within the heat transfer at the interior side [$m^2.K/W$]
θ_e...design exterior temperature [°C]

f_{Rsi} = (20,46 - (-15)) / (21 - (-15)) = 0,985

3) F1- FLOOR IN THE GROUND FLOOR 1 - UNHYDRITE WITH LAMINATE FLOOR

a) THE LOWEST SURFACE TEMPERATURE

$\boldsymbol{\theta_{si,min} = \theta_{a,i} - U \cdot R_{si} \cdot (\theta_{a,i} - \theta_e)}$

where $\theta_{si,min}$ [°C] .... lowest surface temperature
$\theta_{a,i}$...design interior temperature[°C]
U...coefficient of heat transfer [$W/m^2.K$]
R_{SI}...thermal resistance within the heat transfer at the interior side [$m^2.K/W$]
θ_e...design exterior temperature [°C]

$\theta_{si,min}$ =21- 0,23 . 0,17. (21- (5))= 20,37 °C

b) CRITICAL FACTOR

$\boldsymbol{f_{Rsi} = (\theta_{si,min} - \theta_e) / (\theta_{ai} - \theta_e)}$

where f_{Rsi}.. critical factor of internal surface [-]
$\theta_{a,i}$...design interior temperature[°C]
U...coefficient of heat transfer [$W/m^2.K$]
R_{SI}...thermal resistance within the heat transfer at the interior side [$m^2.K/W$]
θ_e...design exterior temperature [°C]

f_{Rsi} = (20,35 - (5)) / (21 - (5)) = 0,959

4) F2 FLOOR IN THE GROUND FLOOR 2- UNHYDRITE WITH CERAMIC TILES

a) THE LOWEST SURFACE TEMPERATURE

$\boldsymbol{\theta_{si,min} = \theta_{a,i} - U \cdot R_{si} \cdot (\theta_{a,i} - \theta_e)}$

where $\theta_{si,min}$ [°C] .... lowest surface temperature
$\theta_{a,i}$...design interior temperature[°C]
U...coefficient of heat transfer [W/m^2.K]
R_{SI}...thermal resistance within the heat transfer at the interior side [m^2.K/W]
θ_e...design exterior temperature [°C]

$\theta_{si,min}$ =21- 0,24 . 0,17. (21- (5))= 20,35 °C

b) CRITICAL FACTOR

$$\mathbf{f_{Rsi} = (\theta_{si,min} - \theta_e) / (\theta_{ai} - \theta_e)}$$

where f_{Rsi}.. critical factor of internal surface [-]
$\theta_{a,i}$...design interior temperature[°C]
U...coefficient of heat transfer [W/m^2.K]
R_{SI}...thermal resistance within the heat transfer at the interior side [m^2.K/W]
θ_e...design exterior temperature [°C]

f_{Rsi} = (20,35 - (5)) / (21 - (5)) = 0,959

1.3 CALCULATION OF SURFACE TEMPERATURE IN CORNERS- GEOMETRICAL THERMAL BRIDGES

1) R1- W1 CORNER BETWEEN CEILING INTO EXTERIOR AND PERIPHERAL WALL

a) CALCULATION OF AVERAGE TEMPERATURE DIFFERENCE ξ_{Rsim}

$$\mathbf{\xi_{Rsim} = 1,05 . (U_i . R_{sik})^{0,69}}$$

where ..ξ_{Rsim}... average temperature difference
R_{sik}...thermal resistance within the heat transfer at the interior side [m^2.K/W]
U_i...coefficient of heat transfer [W/m^2.K].. the worse value in case of different U
U_{R1}= 0,15 W/m^2.K
U_{wall}= 0,20 W/m^2.K - value in the critical area of ring
condition: 0,8< U_{wall} / U_{floor}≤1,25
U_{wall} / $U_{floor=}$ 0,8< 0,75≤1,25= NOT FULLFILLED

EVALUATION WILL BE DONE BY 2D APPROACH

- according to calculation in software AREA 2014 by 2D approach the critical factor is evaluated for **f_{Rsi}= 0,872,** calculation included in apex 2

2) F1- W1 CORNER BETWEEN FLOOR IN CONTACT WITH SOIL AND PERIPHERAL WALL

a) CALCULATION OF AVERAGE TEMPERATURE DIFFERENCE ξ_{Rsim}

$\boldsymbol{\xi_{Rsim} = 1{,}05 \cdot (U_i \cdot R_{sik})^{0{,}69}}$

where ..ξ_{Rsim}... average temperature difference

R_{sik}...thermal resistance within the heat transfer at the interior side [$m^2.K/W$]

U_i...coefficient of heat transfer [$W/m^2.K$].. the worse value in case of different U

U_{floor}= 0,24 $W/m^2.K$

U_{wall}= 0,18 $W/m^2.K$....

condition: $0{,}8 < U_{wall} / U_{floor} \leq 1{,}25$

U_{wall} / U_{floor}= 0,75 <0,8= NOT FULLFILLED

EVALUATION MUST BE DONE BY 2D APPROACH

- according to calculation in software AREA 2014 by 2D approach the critical factor is evaluated for **f_{Rsi}= 0,921** calculation included in apex 2

3) W1- W1 CORNER BETWEEN TWO PERIPHERAL WALLS

a) CALCULATION OF AVERAGE TEMPERATURE DIFFERENCE ξ_{Rsim}

$\boldsymbol{\xi_{Rsim} = 1{,}05 \cdot (U_i \cdot R_{sik})^{0{,}69}}$

where ..ξ_{Rsim}... average temperature difference

R_{sik}...thermal resistance within the heat transfer at the interior side [$m^2.K/W$]

R_{sik}= 0,25 $m^2.K/W$

U_i...coefficient of heat transfer [$W/m^2.K$].. the worse value in case of different U

U_{wall}= 0,18 $W/m^2.K$

U_{wall}= 0,18 $W/m^2.K$....

condition: $0{,}8 < U_{wall} / U_{wall} \leq 1{,}25$

U_{wall} / U_{wall}= $0{,}8<1\leq 1{,}25$ = FULLFILLED

$\xi_{Rsim} = 1{,}05 \cdot (0{,}18 \cdot 0{,}25)^{0{,}69} = 0{,}124$

b) THE LOWEST SURFACE TEMPERATURE

$\boldsymbol{\theta_{si,min} = \theta_{a,i} - \xi_{Rsim} \ (\theta_{a,i} - \theta_e)}$

where $\theta_{si,min}$ [°C] .... lowest surface temperature
$\theta_{a,i}$...design interior temperature[°C]
ξ_{Rsim}... average temperature difference
θ_e...design exterior temperature [°C]

$\theta_{si,min}$ =21- 0,124 . (21- (-15))
$\theta_{si,min}$ = 16,5 °C

c) CRITICAL FACTOR

$\mathbf{f_{Rsi} = (\theta_{si,min} - \theta_e) / (\theta_{ai} - \theta_e)}$

where f_{Rsi}.. critical factor of internal surface [-]
$\theta_{a,i}$...design interior temperature[°C]
U...coefficient of heat transfer [W/m^2.K]
R_{SI}...thermal resistance within the heat transfer at the interior side [m^2.K/W]
θ_e...design exterior temperature [°C]

f_{Rsi} = (16,5 - (-15)) / (21 - (-15)) = 0,875

2. PROTECTION AGAINST IMPACT AND AIRBORN NOISE

2.1 PROTECTION AGAINST AIRBORN NOISE

1) W1 - peripheral wall- airborn noise resistance - wakest point - windows

$R'_w = R_w - k$
R'_w = 36 -2 = 34 dB

where R'_w...weighted constructional airborn noise resistance
R_w... weighted laboratory airborn noise resistance
k... correction, depends on secondary ways of spreading of the noise

$R'_{w,N}$= 30 dB

$R'_{w,N} \leq R'_w$ FULFILLS

Due to the fact that requirements for acoustics are very low in intended area (< 30 dB) and ragarding the thicknenes of thermal insulation of peripheral constructions (see apex 3 - compositions), all the other peripheral constructions are fullfilling this requirement.

$R'_{w,N} \leq R'_w$ FULFILLS

2.1 PROTECTION AGAINST IMPACT NOISE

$\mathbf{R'_{w} = R'_{w,CONCRETE} + R'_{w,\ insulation}}$
kde R'w… weighted laboratory airborn noise resistance [dB]
$\mathbf{R'_{w}} = 70 + 35 = 105$ dB
$\mathbf{R'_{w,N}} = 68$ dB

$\mathbf{R'_{w,CONCRETE}}$... for RC slab of th. 250 mm
$\mathbf{R'_{w,\ insulation}}$ for insulation EPS 100 in th. 50 mm

Composition in apex 3.

$\mathbf{R'_{w,N} \leq R'_{w}}$ **FULFILLS**