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USE OF FOAM GLASS AS A SLAB ON GRADE THERMAL INSULATION

SZKŁO PIANKOWE JAKO TERMOIZOLACJA „PODŁOGI NA GRUNCIE”

Abstract

This paper describes the results of simulation and calculation of heat loss through a slab on grade to the ground. Calculations are performed for a single-family house. The effect of using foam glass as insulating material is analyzed.

Keywords: foam glass, slab on grade, heat losses

Streszczenie

Artykuł opisuje wyniki przeprowadzonych symulacji i obliczeń strat ciepła przez podłogę na gruncie. Obliczenia przeprowadzono dla budynku jednorodzinnego. Przeanalizowano efekt zastosowania szkła piankowego jako materiału termoizolacyjnego.

Słowa kluczowe: szkło piankowe, podłoga na gruncie, straty ciepła

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Symbols

ψ_e – linear thermal transmittance associated with wall/floor junction [W/mK]
L_{2D} – linear thermal feedback coefficient [W/mK]
U_1 – thermal transmittance of basement walls and doors [W/m^{2}K]
U_2, U_m – thermal transmittance of slab on grade (U_2) – mean value (U_m) [W/m^{2}K]
H_{tr} – stationary thermal coupling coefficient for the slab on grade [W/K]
q – heat flux [W]
Q – heat loss for the slab on grade [kWh]

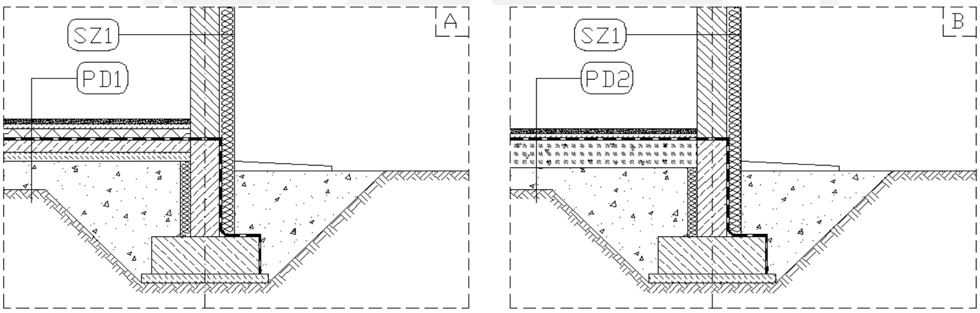
1. What is foam glass?

Foam glass is formed from cullet, which is extracted in the process of glass recycling; among others, from conventional glass bottles. The cullet is mixed with glycerol and foaming agents and, in the form of such a mixture, it is subjected to high temperatures of up to 900°C. The result – a large-size foam glass block – can be rapidly cooled down and, due to this sudden change of temperature, the stress destroys the compact structure. This the way in which a foam glass in the form of aggregate is obtained.

2. The analyzed model

Simulations were carried out for a single-family building without a basement, founded on reinforced concrete strip footing and with the slab on grade.

For this building, the simulation involving the change in designed slab on grade layers to layers suggested by the company Geocell [1] was conducted. Compared solutions are shown



PD1
1. Finishing layer—e.g. tiles / PVC
2. Concrete floor on PE foil
3. Polystyrene foam
4. Damp proofing
5. Reinforced concrete slab
6. Lean concrete base
7. Sand and gravel mix
8. Natural soil

PD2
1. Finishing layer—e.g. tiles / PVC
2. Concrete floor
3. Damp proofing
4. Geocell foam glass (1:1.3 consolidation)
5. Geotextiles
6. Natural soil

SZ1
1. Inner thin-coat plaster work
2. Ceramic masonry wall
3. EPS 70 styrofoam
4. Outer thin-coat plaster work

Fig. 1. Stratification diagram for the analyzed building

in Fig. 1. Slab on grade with the use of foam glass PD2 suggested by the manufacturer [2] were examined in different variants:changing the layer thickness from 15cm to 50cm by 5 cm. The manufacturer recommends using 30 cm layer of foam glass for typical buildings, and 40 cm layer for passive buildings. Spaces with entrances to the building were also considered due to the fact that different thermal bridges are created in these places [3].

3. Simulation results

3.1. Properties of analyzed partitions

The heat loss calculations through the building partitions, computational schemes and values of heat transfer resistance were established based on Polish standard [2]. Thermal resistance for the different layers of materials was determined based on their thickness and thermal conductivity, and adopted depending on the material and in accordance to [4] and [1] for foam glass. From these data, the thermal transmittance coefficient was determined for wall SZ1 and floors PD1 and PD2 (in this case with a variable thickness of the heat insulating layer – from 15 to 50 cm); the obtained values are shown in Table 1.

Table 1

Thermal transmittance

	SZ1	PD1	PD2							
			15 [cm]	20 [cm]	25 [cm]	30 [cm]	35 [cm]	40 [cm]	45 [cm]	50 [cm]
U [W/m²K]	0.17	0.598	0.465	0.36	0.294	0.248	0.212	0.19	0.169	0.153

3.2. Analysis on thermal bridges level

Numerical calculations may be widely used in the analysis of thermal bridges as it is presented in [5]. Computational procedures for determining the building's heat demand which are in force in Poland, allow us to evaluate the effect of thermal bridges in three different ways. The article uses a method of heat flow simulation available in the Therm program. Based on the Polish norm, a computational scheme was adopted (Fig. 2) according to [6], where: l_w is the equivalent thickness for wall SZ1, and $B`$ is a characteristic dimension of floor.

This model, adopted with the applied material properties according to [6], has been subjected to simulation. Due to high ampleness, only exemplary simulation results are hereby attached; they are presented by rendered maps. (Fig. 3) shows the simulation results for a thermal bridge located in places of the door woodwork (Fig. 3a, c, e) and of the junction of outer wall to foundation (Fig. 3b, d, f). The map of heat flux distribution (Fig. 3) presents thermal bridges simulation using 2D models for: floor layers of the finished building PD1 (Fig. 3a and b], PD2 with a 15 cm foam glass layer (Fig. 3c and d) and PD2 with a 50 cm foam glass layer (Fig. 3e and f).

In the simulation, the coefficient for 2D bridges was determined, using a method based on heat flux integration with the use of external dimensions. Subsequently, from the equation (1), the thermal bridge was determined. The results of all thermal bridges simulations described in the article are presented in Table 2.

$$\psi_e = L_{2D} - U_1 \cdot 1.41m - U_2 \cdot 3.30 \text{ m} \tag{1}$$

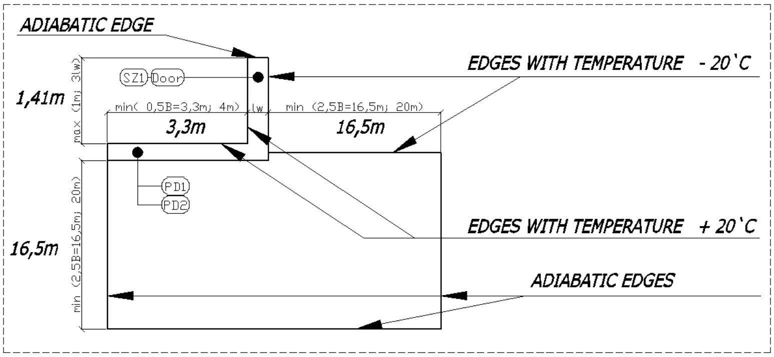
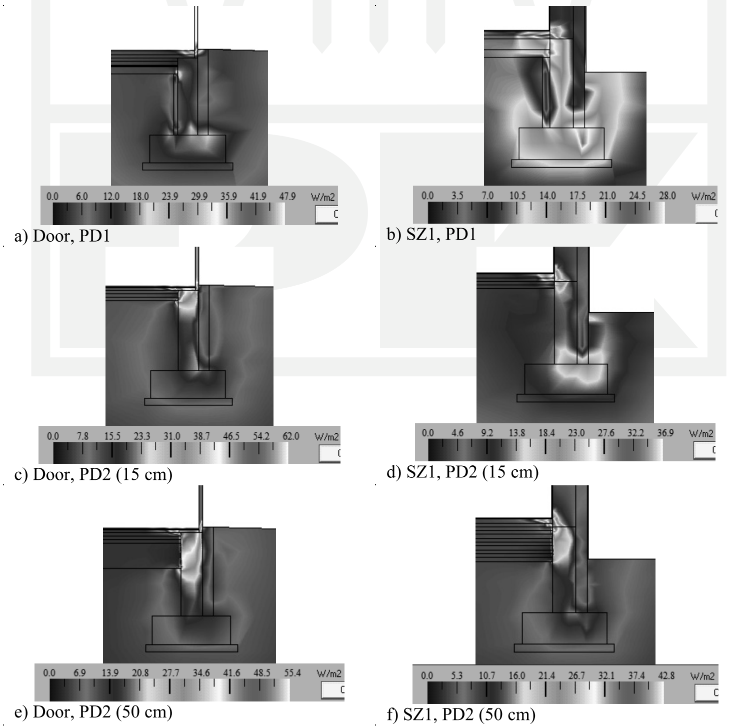


Fig. 2. Computational scheme and boundary conditions by [6]



a) Door, PD1
b) SZ1, PD1
c) Door, PD2 (15 cm)
d) SZ1, PD2 (15 cm)
e) Door, PD2 (50 cm)
f) SZ1, PD2 (50 cm)

Fig. 3. Distribution of the heat flow

Table 2

Linear thermal transmittance associated with wall/floor junction

$\Psi_{e\,[W/mK]}$	PD1	PD2							
		15 [cm]	20 [cm]	25 [cm]	30 [cm]	35 [cm]	40 [cm]	45 [cm]	50 [cm]
Door	–1.91	–1.373	–1.01	–0.795	–0.651	–0.054	–0.465	–0.411	–0.346
SZ1	–1.417	–0.97	–0.63	–0.425	–0.29	–0.196	–0.13	–0.078	–0.037

3.3. Analysis of thermal bridges levels

Severe impact of thermal bridges can have unpleasant consequences [7]. Using practical solutions for the analysis of heat losses through the slab on grade according to [8] and sources previously cited, a heat flux was determined. That heat flux is lost at the junction of the wall and the ground surface through thermal bridges like door woodwork and between slab-outer wall connection. The results were averaged using a weighted average, dependent on the length of the bridge in the total perimeter of the building. Additionally, an average heat transfer coefficient for the slab on grade – U_m – was determined. Subsequently, a stationary thermal coupling coefficient was determined for the slab on grade H_{tr} of 160.88 m^2 area, which gives us the scope to estimate the actual heat loss q for the whole slab on grade, depending on the length of the analyzed period and on outdoor temperatures, which are determined by the location of the building. The results are shown in Table 3.

Table 3

Calculations results as described above

	PD1	PD2							
		15 [cm]	20 [cm]	25 [cm]	30 [cm]	35 [cm]	40 [cm]	45 [cm]	50 [cm]
U_m [W/m^{2}K]	0.219	0.206	0.187	0.173	0.165	0.152	0.144	0.137	0.131
H_{tr} [W/K]	35.17	33.18	30.15	27.84	26.54	24.49	23.12	22.00	21.04
q [W]	1406.74	1327.10	1205.89	1113.53	1061.64	979.63	924.60	880.07	841.46
Q [kWh] January	348.87	329.12	299.06	276.16	263.29	242.95	229.30	218.26	208.68

4. Conclusions

The use of foam glass as a thermal insulating leads to a significant reduction in heat loss for analyzed slab on grade. The analysis of the linear heat loss coefficient presented in Table 2 shows that with the thickness increase of the foam glass layer, the impact of the bridges tends to zero, and the coefficient value for the PD2 layer (15 cm) is about 30 times smaller than for the PD2 layer (50 cm). The values summarized in Table 3 show that a change from traditional solutions to the solution recommended for typical buildings PD2 (30 cm) will reduce the heat loss through the floor by about 25%, while the use of solution for passive buildings PD2 (40 cm) will reduce the heat loss by about 35%. The analysis also shows that increasing the thickness of foam glass layer above 40cm does not yield such good results – that is approximately 40% less heat loss compared to the traditional layer.

References

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