The effect of the building blind area heat insulation on heat losses through the floor on the ground

Elena Malyavina and Elizaveta Gnezdilova
Moscow State University of Civil Engineering, Yaroslavskoe shosse, 26, Moscow, Russia
E-mail: emal@list.ru elizam@yandex.ru

Abstract. The relevance of the problem under studying is the appearance of non-traditional heating insulation structures of the floor on the ground, that can not be subject to calculations of heat losses using the existing methods. The purpose of this article is to find out the average characteristic heat transfer resistances in the design zones adopted in the Russian Federation for thermal protection of the floor on the ground by heat insulating the blind area of the building. Factors essential for possible elimination of condensation on the junction of the floor and the exterior walls were evaluated, as well as the possible maintenance of the floor temperature at the border of the serviced area not below specified values. The method of investigation is the annual calculation of unsteady thermal regime of flooring with the soil massive by finite difference method according to the implicit scheme. As the results we can state a significant impact of the type of soil on the heat loss through the ground floor, an insignificant impact of the width and thickness of the insulated building blind area. The most critical for the possibility of using the blind area heat insulation is the practical inability to provide acceptable temperatures of the floor at the wall-to-floor junction and on the border of the serviced zone. The main conclusion is that the heat insulation of the building blind reaches its goals at the room temperature of 10 °C. But it needs additional small heat insulation of the floor on the ground itself at a room temperature of 20°C and 30°C.

1. Introduction
The heat losses through the floors on the ground in some industrial, commercial and sports buildings make a significant part of the total heating system capacity of these buildings. Therefore, a significant number of studies in Russia [1 – 7] and around the world [8 – 16] are devoted to the calculation of heat losses through the floors on the ground. The mentioned works describe methods for heat losses calculations of various accuracies, but the vast majority of them are focused on traditional heat insulation design structures. In addition, the greatest part of Russia has such a climate that to enable the room compliance to sanitary-and-hygienic parameters provision shall be made of the absence of condensate in the most critical location: at the junction of the floor on the ground and the outer wall with the heat insulation. Besides, the code of rules for thermal protection of the buildings normalizes minimum temperature values on the floor surface.

Therefore, the temperature should be monitored at the border of the serviced area, that is, on the floor surface at a distance of 0.5 m from the outer wall. There are very few works aimed at studying the temperature environment created by various traditional heat insulation structures. For non-
traditional methods of insulation of floors on the ground, which include heat insulation of the building's blind area, considered in the article, the evaluation of heat losses through the floors and estimates of the above temperatures are not known to us.

The complexity of such calculations is explained by the fact that the specified design of the floor heat insulation over the ground is not consistent with the existing methods.

Figure 1 shows a General view of the building cross section with a building insulated blind for thermal protection of the floor on the ground.

![Figure 1](image)

**Figure 1.** The main dimensions adopted for calculating heat losses through the floor on the ground with a heat insulated blind area.

2. Methods

In [2], a method was presented for calculating heat losses through floors on the ground using modern heat insulation structures. It used the results of annual calculations of non-stationary thermal regime of flooring with soil in the climatic conditions of Moscow by the finite difference method according to the implicit scheme using a locally one-dimensional method to align one-dimensional problem to two-dimensional one. As the initial climate information, a "typical" year was used, which method of development has been adopted according to the ISO 15927-4:2005 standard.

Hygrothermal performance of buildings — Calculation and presentation of climatic data — Part 4: Hourly data for assessing the annual energy use for heating and cooling, 2005.

This climatic model for calculation of time-varying processes is adopted throughout the world [17-19.] First, the object has been calculated using climate data from a "typical" year [19], with hourly values of the climate parameters close to the average annual values. This calculation was repeated for 5 years to form the initial temperature distribution in the soil mass. The sixth "typical" year [20] consisted of hourly values of temperature, wind, and solar radiation intensity, which in the cold design period of the year approached the calculated parameters for heating. The coldest five-day period is observed from 17.01 to 21.01. The average outdoor temperature during the coldest five-day period is -25.9 °C, with the absolute minimum reached at -30.5 °C during 24 hours referring to 19.01. Figure 2 shows the temperature state of the soil (loam) in different seasons of the year, when the room has 20°C, the heat insulation of the building blind area with a width of 1 m has a heat transfer resistance of 3.33 m²°C/W. The isotherms show the temperature values.
Figure 2. Isotherms in the soil (loam) massif under a building of 14 m width with an insulated blind area, 1 m wide, with resistance to heat transfer $R_{ins} = 3.33 \text{ m}^2 \cdot \text{°C/W}$ and room temperature $t_{int} = 20 \text{°C}$.

The purpose of this article is to find out by calculation the average characteristic heat transfer resistances in the design zones adopted in the Russian Federation for thermal protection of the floor on the ground by warming the blind area of the building. In addition, it should be found out the possibility of eliminating condensation on the outer wall–to-floor junction, as well as the possible maintenance of the floor temperature at the border of the serviced area not below specified values.

It should be noted, that in the Russian Federation the method "by zones" is adopted for engineering calculation of the ground heat losses. In accordance with this method, the entire floor is divided into zones: strips 2 m wide, the first of which is adjacent to the outer wall, each next zone is located inside the previous one. It is important that at the beginning of the 20th century, O. E. Vlasov and V. D. Machinsky [21, 22] calculated heat losses through structures on the ground in a stationary mode and calculated the resistance to the zone heat transfer of each zone of non-insulated floor. This was a
serious step in a justified application of a simplified problem that is understandable to engineers, since in a non-stationary process there can be no such characteristic of heat transfer through floors as the heat transfer resistance.

This article discusses the insulation of the building's blind area. This type of thermal protection of the floor on the ground is possible, since the luminaries of the construction heat engineering O. E. Vlasov and V. D. Machinsky proved [21, 22] that the building heat distribution occurs along semicircles whose centers are located at the intersection of the inner face of the wall and the floor on the ground. In the article, the characteristic averages for each design zone of the heat transfer resistance in case of the floor thermal protection by insulation of the blind area are developed. The maximum room heat losses are determined by multiplying the heat transfer resistance of a separate zone by its area and the difference between the internal air temperature and the calculated outdoor air temperature for heating.

For the calculation, a cross section of the building with modeling of the two-dimensional temperature soil field together with the floor structures was adopted. The width of the building is adopted in such a way that the floor over the ground covers 3 design zones of 2 m and half of the 4th zone. At all ground boundaries (right, left, and bottom), the condition of no heat flow was accepted. In addition to this size, narrower buildings and wider ones were also considered.

The calculation was carried out for floors lying on the ground level with the soil level. Consideration has been made of the building blind area insulation having a heat transfer resistance ($R_{ins}$) equal to 0.83 m$^2$·°C/W, 1.11 m$^2$·°C/W, 1.67 m$^2$·°C/W and 3.33 m$^2$·°C/W. All sizes are shown in Figure 1.

3. Results and Discussion
First of all provision has been made of considering the necessity of taking into account the type of soil to the heat loss through the floor on the ground and the temperature of the outer wall –to-floor junction, as well as the floor itself at the border of the serviced area, i.e. a distance of 0.5 m from the exterior wall. Figure 3(a) shows that even with a significant heat insulation of 1 m wide blind area in the first design zone, the role of the soil type is not great, but starting from the second zone it becomes significant.

At the same time, the figure 3(b) indicates that the temperature of the wall-to-floor junction and the temperature at the border of the serviced zone do not change much when the soil type changes.

![Figure 3](image-url.png)

**Figure 3.** The role of the soil type in the formation of the thermal state of the floor on the ground in a room with a temperature of 20 °C, resistance to the heat transfer of heat insulation of the blind area with a width of 1 m 3.33 m$^2$·°C/W: a) change in characteristic heat transfer resistances; b) the temperature changes of the wall-to-floor junction and the floor at the border of the serviced area.
The influence of the soil type on the characteristic heat transfer resistances in individual design zones is also evident from the consideration of the relations of these resistances in neighboring zones. For different width and thickness of the blind insulation, the limits of these relations are shown in table 1.

Table 1. The ratio of the average characteristic heat transfer resistances in the neighboring design zones: R2/R1 - the second zone to the first, R3/R2 - the third zone to the second, R4/R3 - the fourth zone to the third.

| Ratio value | R2/R1 | R3/R2 | R4/R3 | R2/R1 | R3/R2 | R4/R3 |
|-------------|-------|-------|-------|-------|-------|-------|
| Minimal     | 5.057 | 1.555 | 1.098 | 4.668 | 1.561 | 1.105 |
| Maximal     | 5.296 | 1.610 | 1.125 | 4.895 | 1.617 | 1.116 |

It can be seen that these ratios are different for different types of soils.

It is interesting, that for a non-heat insulated floor, according to the "by zones" method, the heat transfer resistances of the design zones are 2.1 m²·°C/W for the 1st zone; 4.3 m²·°C/W - for the 2nd zone; 8.6 m²·°C/W – for the 3rd zone; 14.2 m²·°C/W for the 4th zone. Accordingly, the ratio between the heat transfer resistances of the neighboring zones are equal to: 2.05, 2, 1.65. Thus, the resistance to heat transfer of the floor on the ground in the "by zones" method increases evenly when moving from the exterior wall to the center of the building, the intensity of the increase in heat transfer resistance decreases slightly only in the center of the building, in the 4th zone.

However, the data from table 1 show that when the building blind is insulated, the characteristic heat transfer resistance of the 2nd zone increases by 3.5 times or more relative to the 1st zone. When moving further to the center of the building, the resistance to the heat transfer increases much more slowly: on average, the resistance of the 3rd zone increases by 1.5 times relative to the 2nd zone. The difference between the characteristic heat transfer resistance of the 4th and 3rd zones is very small.

Change in the width of the building heat insulated blind area (Bba) from 0.5 m to 5.5 m and the heat transfer coefficient of this insulation (Rins) from 0.83 m²·°C/W up to 6.25 m²·°C/W has a slight effect on the floor temperature at different distances from the outer wall, and therefore on the heat losses and the temperature values under investigation, as can be seen from figure 4.

The same idea is confirmed by figures 5a and 5b. It can be seen that the minimal of the above mentioned insulation heat transfer resistances of 0.83 m²·°C/W an increase in the width of the heat
The insulated blind does not lead either to a significant increase in the characteristic resistance to heat transfer of the floor in different design zones (figure 5a), or to a noticeable increase in the temperature both at the wall-to-floor on the ground junction and at the border of the served zone (figure 5b).

Figure 5. Changes in the thermal performance of the floor on the ground in different design zones with an increase in the width of the building blind area with an insulation heat transfer resistance of 0.83 m²·°C/W: a) characteristic heat transfer resistances; b) temperature values at the outer wall-to-floor on the ground junction, as well as at the border of the served zone.

Calculations have shown that the insulation of the building blind area is not enough to achieve the required floor temperature at the border of the served zone at the internal air temperature $t_{\text{int}} = 20^\circ\text{C}$, as well as to comply with the floor temperature at the junction with the outer wall above the dew point temperature at $t_{\text{int}} = 30^\circ\text{C}$. The required value of the floor temperatures can be achieved by applying a combined heat insulation of the building blind area and the wall part of the floor.

For example, for a pavement of 1.5 m width, which is insulated by the expanded clay gravel with a 600 kg/m³ density and the layer thickness of 160 mm, located on the sandy soils it is sufficient to provide 0.8 m wide additional insulation of the floor wall part with expanded clay gravel, 160 mm thick, to reach the floor temperature at the boundary of the serviced area above 18°C at $t_{\text{int}} = 20^\circ\text{C}$ and the floor temperature at the junction with the wall above 23.2°C at $t_{\text{int}} = 30^\circ\text{C}$. Additional 100 mm thick floor insulation with expanded clay is not enough: the floor temperature at the junction with the wall at $t_{\text{int}} = 30^\circ\text{C}$ is reduced below the dew point, and at $t_{\text{int}} = 20^\circ\text{C}$ the temperature at the border of the served floor area is reduced to 17.54°C, which makes this method suitable only for warming public buildings - it is no longer suitable for housing.

The need for an additional insulation of only the floor wall part is confirmed by the ratios of the characteristic heat transfer resistances of the design zones from the table 1, since the first zone has the greatest impact on the total amount of heat losses through the floor on the ground.

The above results apply to buildings with a width of 14 m. The Verification of the influence of the building width on the main thermo-technical indicators of the floor on the ground was performed for buildings with a width of 14 m, 10 m, 8 m. It is found that the width of the building does not affect the value of the characteristic resistances to the heat transfer in the first design zone (figure 6a), as it does not affect the temperature at the junction of the outer wall with the floor and on the border of serviced area (figure 6b). However, a smaller building width slightly reduces the characteristic heat transfer resistances in the second and the third zones. This situation is totally justified by the fact that when the width of the building, for example, makes 10 m, the fourth zone is absent and there is no influence of the temperature field of the second zone at the formation of the temperature of the third zone.
4. Conclusions
1. Insulation of the building blind area, even with a high heat transfer thermal resistance, is insufficient to maintain the floor temperature not less than the standard values at the junction of the exterior wall and the floor on the ground, as well as at a distance of 0.5 m from the outer wall. The desired floor temperature regime can be achieved by additional floor heat insulation. For this purpose, 160 mm of expanded clay gravel with a density of 600 kg/m³ is sufficient with a strip of 0.8 m at the outer wall and a 1.5 m wide heat insulated blind area.

2. The ratio of heat transfer resistances in certain zones of the floor on the ground differs from the ratio of heat transfer resistances of the non-insulated floor, adopted in the "by zones" method. In the "zone- by- zone" method, the increase in characteristic heat transfer resistances from zone to zone is more uniform than in the presented calculations.

3. The minimum annual temperature at the outer wall-to-floor junction, as well as at the border of the serviced zone, practically does not depend on the width of the building with different widths of the heat insulated blind area. The characteristic heat transfer resistance in the first design zone also does not depend on the width of the building. Starting from the second zone, the characteristic floor heat transfer resistance in the zone is greater, the greater the width of the building. This is because with a wide building more heat enters the floor than with a narrow one.

4. The heat transfer resistance of the building blind thermal insulation has a very little effect on the characteristic resistance in different floor areas. The temperature of the floor junction with the outer wall decreases when the resistance to the heat transfer of the insulation in the blind area is reduced, while the temperature at the border of the served zone remains the same. At the same time, it is 0.5 – 1.2 °C higher than that of the floor without a heat insulation.

References
[1] Vasilyev G P, Gornov V F, Konstantinov P I, Kolesova M V and Korneva I A 2017 Analysis of ground temperature variations, on the basis of years-long measurements Mag. of Civ. Engin. 4 62–72 DOI: 10.18720/MCE.72.8
[2] Malyavina E G, Gnezdilova E A and Levina Yu N 2019 Development of calculated resistances to heat transfer of floors via the ground using modern methods of their thermal protection Build. Mat. 6 44–48 DOI: https://doi.org/10.31659/0585-430X-2019-771-6-44-48 (in Russian)

[3] Samarin O D 2016 Substantiation of the simplified method of determining heat losses through underground parts of building enclosures Vestnik MGSU 1 118–125 DOI: 10.22227/1997-0935.2016.1.118-125 (in Russian)

[4] Volkov N G and Sokolov I S 2018 Comparison of soil temperature measurement by cone penetration testing and borehole thermometry Engineer. Survey XII, Issue 7-8 16–24 https://doi.org/10.25296/1997-8650-2018-12-7-8-16-24 (in Russian)

[5] Levin E V and Okunev A Yu 2019 Heat transfer in soil foundations of buildings. Impact of insulated blind area Build. and Reconsr. 3(83) 83–93 DOI: 10.33979/2073-7416-2019-83-3-83-93 (in Russian)

[6] Vasilev K A 2016 Simulation of air conditioning system in areas of machining of composite materials shipbuilding production Vestnik Gos. Uni. Mor. i Rechn. Flota Im. Adm. S.O. Makarova 6(40) 129–139 DOI: 10.21821/2309-5180-2016-8-6-129-139

[7] Pankova E and Kabanova I 2019 Evaluation of application of recirculation in ventilation and air conditioning systems Engineer. Solut. 8 (9) URL: https://journaltech.ru/archive/9/181 (accessed: 06.03.2020) DOI: 10.32743/2658-6479.2019.8.9.181

[8] Zhong Zh and Braun J E 2007 A simple method for estimating transient heat transfer in slab-on-ground floors Build. and Envir. 42, Issue 007 1071–80 https://doi.org/10.1016/j.buildenv.2005.01.030

[9] Wang Y, Jiang Ch, Liu Y, Wang D and Liu Ji 2018 The effect of heat and moisture coupling migration of ground structure without damp-proof course on the indoor floor surface temperature and humidity: Experimental study Ener. and Build. 1581 580–594 https://doi.org/10.1016/j.enbuild.2017.10.064

[10] Chen D 2014 Unified solutions for steady-state ground-coupled heat transfer Ener. and Build. A 68 444–459 https://doi.org/10.1016/j.enbuild.2013.04.029

[11] Chen D 2017 Heat loss via concrete slab floors in australian houses procedia Engineering 205 108–115 https://doi.org/10.1016/j.proeng.2017.09.941

[12] Baglivo C, Congedo P M 2019 Optimization of high efficiency slab-on-ground floor by multi-objective analysis for zero energy buildings in mediterranean climate Journal of Build. Engineer. 24 100733 https://doi.org/10.1016/j.jobe.2019.100733

[13] Pelsmakers S and Elwell C A 2017 Suspended timber ground floors: Heat loss potential of insulation interventions Ener. and Build. 15315 549–563 https://doi.org/10.1016/j.enbuild.2017.07.085

[14] Pelsmakers S, Fitton R, Biddulph P, Swan W and Elwell C A 2017 Heat-flow variability of suspended timber ground floors: Implications for in-situ heat-flux measuring Ener. and Build. 1381 396–405 https://doi.org/10.1016/j.enbuild.2016.12.051

[15] Lu Ji, Xue Yu, Wang Zhi and Fan Y 2020 Optimized mitigation of heat loss by avoiding wall-to-floor thermal bridges in reinforced concrete buildings Journal of Build. Engineer. 30 101214 https://doi.org/10.1016/j.jobe.2020.101214

[16] Chen F and Richman R 2020 The effect of shallow depth horizontal ground loop clearance on the heat loss of a single family residential dwelling Journal of Build. Engineer. 29 101185 https://doi.org/10.1016/j.jobe.2020.101185

[17] Malyavina E G, Malikova O Yu 2018 Comparison of the completeness of the climate probability-statistic model and the reference year model IOP Conf. Ser.: Materials Sci. and Engineer. vol 365 022009 (Smart City) doi:10.1088/1757-899X/365/2/022009

[18] Barreira E, Simões M L, Delgado J M P Q and Sousa I 2017 Procedures in the construction of a test reference year for Porto-Portugal and implications for hygrothermal simulation Sust. Cities and Soc. 32 397–410 https://doi.org/10.1016/j.scs.2017.04.013

[19] Siu Ch Y and Liao Z 2020 Is building energy simulation based on TMY representative: A
comparative simulation study on doe reference buildings in Toronto with typical year and historical year type weather files

Ener. and Build. 211 109760
https://doi.org/10.1016/j.enbuild.2020.109760

[20] Malyavina E G and Ivanov D S 2014 Development of the design reference year for calculation of heat loss via buildings underground part Proc. of Voeikov Main Geophys. Observatory 571 184 – 193 (in Russian)

[21] Vlasov O E 1938 Basics of Constructional Heat Technology (Moscow: VIA) p 94 (In Russian)

[22] Machinkiy V D 1939 Heat Transfer in Construction (Moscow: Gosstroyizdat) p 343 (In Russian)