Influence of thermal insulation of the wall area of the floor on the ground on the heat loss amount

E G Malyavina\textsuperscript{1} and E A Gnezdilova\textsuperscript{2}

\textsuperscript{1}Moscow State University of Civil Engineering, 26, Yaroslavskoye Shosse, 129337, Moscow, Russia

E-mail: elizam@yandex.ru

Abstract. The relevance of the study is explained by the fact that in the Russian Federation, the “by zone” method of heat loss calculations of the floor on the ground does not allow considering various factors that affect heat losses. As the heat loss studying method, this work adopts the calculation of the non-stationary annual thermal regime of floors together with the soil mass. There is no such thermal protection indicator as the heat transfer resistance in a non-stationary thermal process, therefore the paper uses a characteristic, in other words, a conditionally reduced one for heat loss calculations through the floor on the ground in stationary thermal conditions. The purpose of this article is to calculate the average characteristic heat transfer resistances for each design zone for thermal protection of the wall area of the floor on the ground with different width of the insulation stripe and heat transfer insulation resistance. The considerable result of the work is detection of significant impact of the soil type, the width of the floor insulation stripe, and the actual resistance to heat transfer of this insulation on the characteristic heat transfer resistance in the first design zone. It follows from the study that the floor thermal insulation stripe in the wall area is the most effective structure of the floor thermal protection, both in terms of reducing heat losses, and in terms of compliance with the temperature standards for the floor.

1. Introduction

Heat losses through the floors on the ground play a significant role only in the buildings that have a larger floor area than the surface areas of the external walls and windows. These buildings include some industrial, warehouse, retail and sports constructions. Therefore, the development of methods for calculating heat losses through the floors on the ground is the goal of quite a large number of works in the Russian Federation [1-5] and abroad [6-13].

Nowadays, various methods of thermal protection of the floors on the ground are applied, i.e. thermal insulation of the outer wall below the ground level to a considerable depth, insulation of the building blind area and others. However, the classic and long-existing method is the thermal insulation the floor on the ground itself (Figure 1).

But even so, in the seemingly evident and obvious method of the floor thermal protection, there are several unclear issues. It is not clear whether the type of the soil or the width of the wall insulation stripe affect the characteristic heat transfer resistances of particular design zones. In addition, it is not clear what kind of thermal insulation of the area close to the wall area is sufficient to prevent condensation at the junction on the ground floor and the exterior wall, as well as to achieve the permissible floor temperature at the boundary of the serviced area, i.e. at a distance of 0.5 m from the outer wall.
The issue is complicated by the fact that the formation of heat losses through the floor on the ground occurs in a non-stationary annual thermal regime of the soil mass together with the floor, and the application of the characteristics of the floor thermal insulation in the design practice is carried out in a simplified way all over the world. Different floor areas are subject to determination of design heat transfer resistances, which are used in calculating heat losses through the floor in a stationary heat process. In the Russian Federation, a “by zone” method of calculating heat losses through the floor was proposed by O. E. Vlasov [14] and V. D. Machinsky [15] in the 30s of the last century. There is also quite a lot of works abroad which determine the stationary heat transfer characteristics of the floors on the ground [16-20]. In the proposed article, "stationary" heat transfer resistances for various design zones of the floor on the ground are called characteristic in contrast to the real heat transfer resistances of all layers of the floor, which can be simply calculated and measured.

2. Methods
The purpose of this article is to determine the relationship between the thermal insulation stripe width of the wall area of the floor on the ground and the real heat transfer resistance of this insulation with the values of the average characteristic resistances to heat transfer for each design zone. Verification of the floor temperature at the junction with the outer wall to avoid condensation, as well as the floor temperature at the border of the serviced area not lower than the normalized values, have been considered as important tasks as well.

The sufficiency of the floor thermal insulation has been checked at the indoor air parameters shown in the Table 1.

Table 1. Minimum permissible floor temperatures at the junction with the outer wall and at the border of the serviced area.

| Premises     | Air temperature, °C | Relative air humidity, % | Dew point, °C | Temperature at the distance of 0.5 m from the external wall, °C |
|--------------|----------------------|--------------------------|---------------|---------------------------------------------------------------|
| Warehouses   | 10                   | 50                       | 0.1           | 7.5                                                           |
| Residential  | 20                   | 55                       | 10.7          | 18                                                            |
| Public       | 20                   | 50                       | 9.3           | 17.5                                                          |
| Swimming     | 30                   | 67                       | 23.2          | 27.5                                                          |
The assigned tasks have been solved by calculation. The calculation method is presented in [2]. The procedure uses the calculation of the non-stationary annual thermal regime of the floors together with the soil mass in the climatic conditions of Moscow by the method of finite differences using an implicit scheme. The "standard" year [21] has been adopted as the initial climatic information, and the methodology for its development has been adopted in accordance with ISO 15927-4:2005 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.

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 of 19.01.

3. Results and Discussion

The performed multi-variant calculations allowed the analysis of the influence of a number of factors on the characteristic average heat transfer resistances in individual design zones. The design zones represent 2 m wide stripes numbered starting from the outer wall. Moreover, the zone IV includes the entire floor area that was not included in the first three ones.

The influence of the soil type is shown in the Figure 2. It considers the case of a 2 m floor wall area thermal insulation with a real resistance to heat transfer of insulation of 0.83 m²·°C/W. At the same soil heat capacity in the thawed soil $C_{th}=3150$ kJ/(m³·°C) and permafrost soil $C_{f}=2350$ kJ/(m³·°C) the thermal conductivity of the soils has been taken as follows: loam 1.68 W/(m·°C), sandy loam 1.91 W/(m·°C), sand 2.73 W/(m·°C) in the frozen state; and in the thaw state - 1.51 W/(m·°C), 1.80 W/(m·°C) and 2.50 W/(m·°C), respectively.

![Figure 2. Influence of the soil type on: a- average values of characteristic heat transfer resistances in the design zones; b- the floor temperature values at the wall-to-floor junction and at the border of the serviced zone.](image)

It follows from the calculations that the soil type has the greatest influence on the value of the characteristic stationary heat transfer resistance in the zone 1, which is closest to the outer wall. For the floors on sandy soils, it is reduced by 0.67 m²·°C/W compared to loams, which makes about 20%. However, the average fixed characteristic resistance of the zones 2 to 4 varies within 1%. At the same time, there is no temperature change at the junction of the floor and the outer wall, as well as at the border of the serviced area.

The influence of the thermal insulation stripe width in the wall area is shown in the Figure 3. The figure shows a noticeable decrease in the heat loss value through the floor in the first design zone. However, starting from the second zone, a wider insulation strip gives an opposite effect: the heat losses decrease at a bigger distance from the outer wall, but the heat losses through the floor in the same zone increase slightly with a wider insulation strip. This can be explained by the fact that the
insulation stripe not only protects the room from the cold floor, but also does not allow the ground to be warmed by the premise.

![Figure 3](image-url)  
**Figure 3.** Influence of the width of the thermal insulation stripe \( b \) on the floor on a sandy ground with the real heat transfer resistance \( R_{\text{ins}} = 1.667 \, \text{m}^2 \cdot \circ\text{C}/\text{W} \): a - on the amount of heat loss in the design zones, b - on the floor temperature at the wall-to-floor junction and on the border of the serviced zone.

When changing the wall thermal insulation width from 0.8 m to 2.0 m, the floor temperature changes within 0.12°C, that is, the width of the wall thermal insulation stripe, despite a significant impact on the overall value of heat losses through the floor on the ground, is not an effective tool to regulate the temperature parameters (and therefore, to achieve the thermal comfort).

An interesting result has been revealed when calculating the heat losses through the floor on the ground with the same width of the thermal insulation stripe of the wall zone, equal to 0.8 m, but with different real heat transfer resistance of the thermal insulation. The Figure 4 shows that the heat losses in the first design zone increase when the real resistance to heat transfer decreases from 3.33 \( \text{m}^2 \cdot \circ\text{C}/\text{W} \) up to 0.83 \( \text{m}^2 \cdot \circ\text{C}/\text{W} \) more than 25% of the larger heat losses. Heat losses in the other design zones are almost independent of the actual heat transfer resistance of the thermal insulation stripe.

The effect of reducing the thermal insulation heat transfer resistance within the above limits leads to a decrease in the temperature of the floor joint with the outer wall by 2.3 °C and at the border of the serviced area by 1.4 °C, but all the achieved temperature values are higher than the permissible ones.
Figure 4. Influence of the real heat transfer resistance of the floor thermal insulation with a width of 0.8 m: a - on the heat loss amount in the calculated zones and b - on the floor temperature at the wall-to-floor junction and on the border of the serviced zone.

The question of the permissible minimum real resistance to heat transfer of the floor wall stripe thermal insulation at the outer wall is of importance for designing the floors on the ground. The Figure 5 shows the relationship between the width of the thermal insulation stripe and the required real resistance to the thermal insulation heat transfer at a room temperature $t_{\text{int}}$ of 20 °C and 30 °C.

The calculations showed that the thermal insulation of the floor on the ground with a wall strip which has the real heat transfer resistance of the thermal insulation indicated in the graphs of Figure 5 for buildings of any purpose enables the temperature at the junction of the floor on the ground with the outer wall above the dew point temperature. For warehouses with an internal air temperature of 10 °C, to meet the condition of limiting the lower temperature at the border of the serviced zone, it is sufficient to provide a thermal insulation stripe, 0.8 m wide, and a real heat transfer resistance of 0.4 m²·°C/W.

The lower values of the required thermal insulation of the floor of swimming pools in comparison with residential premises can be explained by the Russian lower normalized difference in the temperature of the indoor air and the floor for residential buildings of 2 °C compared to 2.5 °C of the swimming pools. At the same indoor air temperature as for residential premises of 20 °C, but with a normalized temperature difference of 2.5 °C for public premises, the minimum permissible real heat transfer resistance of the floor thermal insulation is lower than for a swimming pool.
In general, when providing the thermal insulation of the floor wall area, it can be noted that a significant influence on the floor temperature at the border of the served zone has an insulation of up to 1 m wide. A further increase in the width of the insulation stripe is determined not by the heat engineering requirements for the floor temperature, but by the need to reduce heat losses through the floors on the ground.

Since various floor thermal insulation designs are currently used in the construction practice, it has been interesting to compare their effectiveness. The Figure 6 shows the calculation results of heat loss through the floor on the ground and the temperature values at the critical points of the floor on the loam soil with a real insulation heat transfer resistance of 3.33 m²·°C/W. The figure compares options for the thermal insulation of the outer wall, the wall area of the floor and the building blind area.

In all cases, the width of the thermal insulation stripe made 1 m. It is seen that the thermal insulation of the floor itself is the most effective for the floor in the first design zone, and in other zones of the heat losses through the floor even slightly exceed the heat losses at other ways of the thermal insulation due to the soil thermal insulation from the warm indoor air.

The temperature at the junction of the floor with the outer wall and at the border of the serviced area is predictably higher in the version with the thermal insulation of the floor itself. Slightly higher heat losses and lower values of critical temperatures in the option of the outer wall thermal insulation in the ground compared to the option of the blind area thermal insulation can be explained by higher ground temperatures around the building when provision is made of thermal insulation of the building blind area.

![Figure 6](image)

**Figure 6.** Comparison of the effectiveness of various options for thermal insulation of the floor on the ground: a-comparison of heat losses, b-comparison of critical temperature values. 1-thermal insulation of the underground part of the outer wall; 2 – thermal insulation of the wall area of the floor; 3 – thermal insulation of the building blind area.

Since often the floor thermal insulation is accompanied by the thermal insulation of the outer wall, which is usually not taken into account in the calculations, some series of calculations of these options have been performed.

The Figure 7 shows the option of the wall thermal insulation of the floor with a stripe in comparison with the underground part of the outer wall, when the lower limit of the outer wall thermal insulation coincides with the lower boundary of the thermal insulation under the floor and when the thermal insulation on the outer wall is lowered by only 0.3 m. The figure shows that even such a slight additional thermal insulation of the outer walls gives a noticeable effect, both in terms of reducing heat losses, especially in the first design area, and increased temperatures at critical points of the floor.
Figure 7. The effect of additional thermal insulation of the external wall in the ground on a- floor heat losses in various design zones; b -on the floor temperature values at critical points. 1 – at the lower border of the thermal insulation on the outer wall coincident with the bottom limit of the thermal insulation under the floor; 2 – at the lower limit of the thermal insulation on the wall below the lower limit of the thermal insulation on the floor to 0.3 m.

4. Conclusions
1. The floor thermal insulation with a stripe in the wall area is the most effective design of the floor thermal protection, both in terms of reducing heat losses due to a significant reduction in the first design zone, and in terms of compliance with the temperature standards at the junction of the floor with the outer wall and at the border of the serviced zone.

2. The width of the thermal insulation stripe greater than 1 m in the wall area does not lead to a heat loss reduction in all the design zones, except the first one, since such an insulation leads to the thermal insulation of the ground from a warm room.

3. The minimum permissible real heat transfer resistance of the thermal insulation of the floor wall stripe is reduced by increasing the permissible difference in the air temperature of the room and the floor.

References
[1] Vasilyev G P, Gornov V F, Konstantinov P I, Kolesova M V and Korneva I A 2017 Mag. of Civ. Engin. 4 62 DOI: 10.18720/MCE.72.8
[2] Malyavina E G, Gnezdilova E A and Levina Yu N 2019 Build. Mat. 6 44 DOI: https://doi.org/10.31659/0585-430X-2019-771-6-44-48
[3] Samarin O D 2016 Vestnik MGSU 1 118 DOI: 10.22227/1997-0935.2016.1.118-125
[4] Volkov N G and Sokolov I S 2018 Engineer. Survey XII(7-8) 16 https://doi.org/10.25296/1997-8650-2018-12-7-8-16-24
[5] Levin E V and Okunev A Yu 2019 Build. and Reconstr. 3(83) 83 DOI: 10.33979/2073-7416-2019-83-3-83-93
[6] Zhong Zh and Braun J E 2007 Build. and Envir. 42(007) 1071 https://doi.org/10.1016/j.buildenv.2005.01.030
[7] Wang Y, Jiang Ch, Liu Y, Wang D and Liu Ji 2018 Ener. and Build. 1581 580 https://doi.org/10.1016/j.enbuild.2017.10.064
[8] Chen D 2014 Ener. and Build. A 68 444 https://doi.org/10.1016/j.enbuild.2013.04.029
[9] Chen D 2017 Engineering 205 108 https://doi.org/10.1016/j.proeng.2017.09.941
[10] Baglivo C, Congedo P M 2019 Journal of Build. Engineer. 24 100733 https://doi.org/10.1016/j.jobe.2019.100733
[11] Pelsmakers S and Elwell C A 2017 *Ener. and Build.* **153**15 549 https://doi.org/10.1016/j.enbuild.2017.07.085

[12] Zhao J R, Sang Yi, Sun J, Chen B, Zhang X and Kerekes R J 2016 *Ener. and Build.* **133** 541 https://doi.org/10.1016/j.enbuild.2016.10.015

[13] Lu Ji, Xue Yu, Wang Zhi and Fan Y 2020 *Journal of Build. Engineer.* **30** 101214 https://doi.org/10.1016/j.jobe.2020.101214

[14] Vlasov O E 1938 *Basics of Constructional Heat Technology* (Moscow: VIA) p 94

[15] Machinkiy V D 1939 *Heat Transfer in Construction* (Moscow: Gosstroyizdat) p 343

[16] Anderson E A 1991 *Build. and Envir.* **26** 405

[17] Landman K A and Delsante A E 1987 *Build. and Envir.* **22**(1) 57 https://doi.org/10.1016/0360-1323(87)90041-2

[18] Delsante A E 1988 *Build. and Envir.* **23**(1) 11–17 https://doi.org/10.1016/0360-1323(88)90012-1

[19] Dilmac S, Guner A, Senkal F and Kartal S 2007 *Energy Conversion and Manag.* **48**(3) 826 https://doi.org/10.1016/j.enconman.2006.08.015

[20] Delsante A E 1989 *Build. and Envir.* **24**(3) 253 https://doi.org/10.1016/0360-1323(89)90039-5

[21] Malyavina E G and Ivanov D S 2014 *Proc. of Voeikov Main Geophys. Observatory* **57** 184