Comparative Analysis of the Effect of Different Types of Green Roofs over the Linear Thermal Bridges

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Abstract. During recent years, it appears in the background of global discussions the negative impact resulted from the daily humans’ activities. Taking into account the present surface of the built environment and also the fact that this area will significantly increase shortly, it can be considered that using the buildings to develop new solutions like green roofs. The expanding benefits of a green roof emphasize the key role of this structure in the overall thermal performance of buildings and microclimate conditions of indoor spaces. The main objective of the study is to analyse and to interpret the influence of all three main categories of a green roof on the heat flow, in the thermal bridges developed structurally in buildings. The study based on the structural elements of each type of roof, their thermic characteristics and the principal types of thermal bridges will represent a comparison between the thermal impact of a classical terrace roof and that of the extensive, semi-intensive and intensive green roof. In conclusion, the unpredictable results obtained for the analysed thermal parameters let conclude that the green roof solution in all the three forms has an environmental impact, in terms of both sustainability and aesthetics.

1. Introduction
In recent years, many countries have been dealing with different challenges, such as environmental damage, climatic parameters change, and energy losses. These problems represent the principal key for creating and implementing various types of systems, like green roofs and green walls. There is a big chance to partially mitigate the effects of these problems. In this context, the governments of many countries have promoted and encouraged the implementation of new sustainable solutions, and the green roof technology has a priority place due to the decrease of the green space in cities [1- 4]. Being an ecological strategy, continuously developing, green roof systems can minimize water runoff [5], improve the urban heat island effect [6, 7], and decrease carbon emissions [8, 9]. As an element of the green infrastructure, green roofs contribute to the improvement of the air quality, urban drainage outflow reduction, and the urban heat island effect mitigation. In this context, it is essential to understand the role of each roof layers and provide their proper design.

Even if the benefits of the green roofs are permanently investigated in the specialty literature, there is a lack of standards at the European level related to the determination of these advantages and the most difficult is the calculation of the thermal resistance of growing media and drainage layer [10]. In this context, during the years 2009-2013, the Construction Technologies Institute of National Research Council of Italy started an experimental program [11] concentrated on the
thermal characteristics of the growing media for the green roof systems. This experiment was based on the laboratory tests and the results determined the conductivity of different types of growing media, which are the most common in the technology of green roof.

The present research focuses on the comparison between the classical roof and the main types of green roof, extensive green roof, semi-intensive and intensive. The study was carried out using thermal simulations using the RDM 6.17 software. The main purpose of the paper is to analyse and compare the thermal parameters of the four types of roof named previously through computer simulations. For every type of roof were established the structural components and the properties of the material.

2. Study cases

The envelope of the building is defined as an architectural element that acts as a separator between the interior and exterior space of the building. The thermal resistance of building envelope is an important factor directly connected with the total energy consumption and the optimal thermal comfort. In this context, a comparative study of the effect of the principal types of a green roof over the linear thermal bridges can highlight important aspects related to the reduction of urban heat island (UHI) [12].

For the simulation of the case studies, specialized software was used for designing and for the thermal analysis of the thermal bridges of four different types of roofs. These programs are known as AutoCAD [13], which provide the graphic models, and RDM 6.17 [14] which provides indicators of thermal bridges, like heat fluxes, the thermal effect of each type of roof analysed.

2.1. Study on the structure of the four types of roof analysed

In this study, four types of the roof were taken into account, thus the study aimed at comparing the thermal transfer coefficient for four thermal bridges, being considered the most representative types and with the highest impact on thermal behaviour in a building. Thus, table 1 shows the types of roof studied and their notations for easier understanding and follow-up of calculations.

In the case of the first thermal bridge, are made two sets of calculations: one for the roof, and the second for the wall. Table 2 presents the properties of materials for the exterior wall.

| Table 1. Notations used for the structure of the four types of roof analysed. |
|---|---|
| Roof type analysed | Notations |
| The classical roof | a |
| The extensive green roof | b |
| The semi-intensive green roof | c |
| The intensive green roof | d |

| Table 2. The material properties for the exterior wall. |
|---|---|---|---|---|
| Envelope materials | Thickness (d) [m] | ρ [kg/m³] | λ [W/m.K] | C [J/Kg.K] |
| Inner plaster | 0.015 | 840 | 0.870 | 1700 |
| Masonry | 0.250 | 1800 | 0.800 | 870 |
| Vapour barrier | 0.015 | 1700 | 0.380 | 1460 |
| Insulating coating | 0.200 | 20 | 0.044 | 1460 |
| Mortar | 0.015 | 1800 | 0.930 | 840 |
| Exterior plaster | 0.025 | 840 | 0.870 | 1700 |
Tables 3, 4, 5 and respectively 6, show the main characteristics of each type of roof analysed, data that was used for calculations and analysis in the RDM 6.17 program. These properties are as follows: layer thickness, bulk density (\(\rho\)), the coefficient of thermal conductivity (\(\lambda\)), and heat mass capacity (\(C\)).

| Envelope materials | Thickness (d) [m] | \(\rho\) [kg/m\(^3\)] | \(\lambda\) [W/m.K] | \(C\) [J/Kg.K] | The component layers of a) the classical roof |
|---------------------|-------------------|-----------------------|------------------|----------------|-----------------------------------------|
| Inner plaster       | 0.015             | 840                   | 0.870            | 1700           |                                         |
| Reinforced concrete slab | 0.150       | 2500                  | 1.740            | 840            |                                         |
| Masonry             | 0.250             | 1800                  | 0.800            | 870            |                                         |
| Concrete slope      | 0.020             | 1800                  | 0.830            | 840            |                                         |
| Vapour barrier      | 0.010             | 1700                  | 0.380            | 1460           |                                         |
| Insulating coating  | 0.300             | 20                    | 0.044            | 1460           |                                         |
| Waterproofing bracket | 0.010      | 1800                  | 0.930            | 840            |                                         |
| Diffusion layer     | 0.010             | 600                   | 0.170            | 1460           |                                         |
| Waterproofing layer | 0.015             | 600                   | 0.170            | 1460           |                                         |
| Waterproofing protection | 0.100     | 1800                  | 0.700            | 840            |                                         |
| Exterior plaster    | 0.025             | 840                   | 0.870            | 1700           |                                         |

| Envelope materials | Thickness (d) [m] | \(\rho\) [kg/m\(^3\)] | \(\lambda\) [W/m.K] | \(C\) [J/Kg.K] | The component layers of b) extensive green roof |
|---------------------|-------------------|-----------------------|------------------|----------------|-----------------------------------------|
| Inner plaster       | 0.015             | 840                   | 0.870            | 1700           |                                         |
| Reinforced concrete slab | 0.150       | 2500                  | 1.740            | 840            |                                         |
| Vapour barrier      | 0.010             | 1800                  | 0.800            | 870            |                                         |
| Insulating coating  | 0.300             | 20                    | 0.044            | 1460           |                                         |
| Waterproofing bracket | 0.010      | 1800                  | 0.930            | 840            |                                         |
| Diffusion layer     | 0.010             | 600                   | 0.170            | 1460           |                                         |
| Waterproofing layer | 0.015             | 600                   | 0.170            | 1460           |                                         |
| Profile membrane    | 0.010             | 150                   | 0.700            | 1460           |                                         |
| Anti-root layer     | 0.010             | 150                   | 0.700            | 1700           |                                         |
| Geotextile          | 0.002             | 150                   | 0.100            | 1700           |                                         |
| Drainage layer      | 0.020             | 930                   | 0.077            | 2330           |                                         |
| Air layer           | 0.020             | 1.230                 | 0.025            | 0.24           |                                         |
| Filter layer        | 0.002             | 1700                  | 0.380            | 1460           |                                         |
| Soil layer          | 0.100             | 1370                  | 0.250            | 800            |                                         |
| Mortar              | 0.010             | 1800                  | 0.930            | 840            |                                         |
| Cork layer          | 0.004             | 120                   | 0.040            | 2500           |                                         |
| Gravel layer        | 0.100             | 1800                  | 0.700            | 840            |                                         |
| Masonry             | 0.250             | 1800                  | 0.800            | 870            |                                         |
| Exterior plaster    | 0.025             | 840                   | 0.870            | 1700           |                                         |
Table 5. The material properties for the envelope with a semi-intensive green roof.

| Envelope materials | Thickness(d) [m] | $\rho$ [kg/m$^3$] | $\lambda$ [W/m.K] | $C$ [J/Kg.K] | The component layers of c) semi-intensive green roof |
|---------------------|------------------|-------------------|-------------------|-------------|---------------------------------------------------|
| Inner plaster       | 0.015            | 840               | 0.870             | 1700        |                                                   |
| Reinforced concrete |                  |                   |                   |             |                                                   |
| Slab               | 0.150            | 2500              | 1.740             | 840         |                                                   |
| Vapour barrier     | 0.010            | 1800              | 0.800             | 870         |                                                   |
| Insulating coating | 0.300            | 20                | 0.044             | 1460        |                                                   |
| Waterproofing bracket | 0.010      | 1800              | 0.930             | 840         |                                                   |
| Diffusion layer    | 0.010            | 600               | 0.170             | 1460        |                                                   |
| Waterproofing layer | 0.015          | 600               | 0.170             | 1460        |                                                   |
| Profile membrane   | 0.010            | 150               | 0.700             | 1460        |                                                   |
| Anti-root layer    | 0.010            | 150               | 0.700             | 1700        |                                                   |
| Geotextile         | 0.002            | 150               | 0.100             | 1700        |                                                   |
| Drainage layer     | 0.040            | 930               | 0.077             | 2330        |                                                   |
| Air layer          | 0.040            | 1.230             | 0.025             | 0.24        |                                                   |
| Filter layer       | 0.002            | 1700              | 0.380             | 1460        |                                                   |
| Soil layer         | 0.200            | 1370              | 0.250             | 800         |                                                   |
| Mortar             | 0.010            | 1800              | 0.930             | 840         |                                                   |
| Cork layer         | 0.004            | 120               | 0.040             | 2500        |                                                   |
| Gravel layer       | 0.100            | 1800              | 0.700             | 840         |                                                   |
| Masonry            | 0.250            | 1800              | 0.800             | 870         |                                                   |
| Exterior plaster   | 0.025            | 840               | 0.870             | 1700        |                                                   |

Table 6. The material properties for the envelope with an intensive green roof.

| Envelope materials | Thickness(d) [m] | $\rho$ [kg/m$^3$] | $\lambda$ [W/m.K] | $C$ [J/Kg.K] | The component layers of d) the intensive green roof |
|---------------------|------------------|-------------------|-------------------|-------------|---------------------------------------------------|
| Inner plaster       | 0.015            | 840               | 0.870             | 1700        |                                                   |
| Reinforced Concrete |                  |                   |                   |             |                                                   |
| Slab               | 0.150            | 2500              | 1.740             | 840         |                                                   |
| Vapour barrier     | 0.010            | 1800              | 0.800             | 870         |                                                   |
| Insulating coating | 0.300            | 20                | 0.044             | 1460        |                                                   |
| Waterproofing bracket | 0.010      | 1800              | 0.930             | 840         |                                                   |
| Diffusion layer    | 0.010            | 600               | 0.170             | 1460        |                                                   |
| Waterproofing layer | 0.015          | 600               | 0.170             | 1460        |                                                   |
| Profile membrane   | 0.010            | 150               | 0.700             | 1460        |                                                   |
| Anti-root layer    | 0.010            | 150               | 0.700             | 1700        |                                                   |
| Geotextile         | 0.002            | 150               | 0.100             | 1700        |                                                   |
| Drainage layer     | 0.060            | 930               | 0.077             | 2330        |                                                   |
| Air layer          | 0.060            | 1.230             | 0.025             | 0.24        |                                                   |
| Filter layer       | 0.002            | 1700              | 0.380             | 1460        |                                                   |
| Soil layer         | 0.400            | 1370              | 0.250             | 800         |                                                   |
| Mortar             | 0.010            | 1800              | 0.930             | 840         |                                                   |
| Cork layer         | 0.004            | 120               | 0.040             | 2500        |                                                   |
| Gravel layer       | 0.100            | 1800              | 0.700             | 840         |                                                   |
| Masonry            | 0.250            | 1800              | 0.800             | 870         |                                                   |
| Exterior plaster   | 0.025            | 840               | 0.870             | 1700        |                                                   |
2.2. Study on the four types of thermal bridges analysed

In the presented study, four types of thermal bridges were taken into account, namely: the exterior wall intersection with the roof slab (attic); the filled interior wall intersection with roof slab; the empty interior wall intersection with roof slab and the reinforced concrete beam intersection with roof slab.

In table 7, the notations used during the analysis are presented and highlights the important elements for the present study, $T_i = +20^\circ C$ and $T_e = -18^\circ C$.

| Thermal bridges analysed | Notations | The thermal bridges details |
|--------------------------|-----------|-----------------------------|
| The exterior wall intersection with the roof slab (attic) | 1 | ![Diagram 1] |
| The filled interior wall intersection with the roof slab | 2 | ![Diagram 2] |
| The empty interior wall intersection with the roof slab | 3 | ![Diagram 3] |
| The reinforced concrete beam intersection with the roof slab | 4 | ![Diagram 4] |

2.3. Study on thermal bridges analysed for the four types of roof

According to the data previously presented, the four types of thermal bridges were combined with each roof structure, in this way were established 16 thermal bridges analysed. Therefore, table 8, table 9, table 10 and table 11 present the codes used in the performed assessment with the details for the thermal bridges of all the four roofs.
### Table 8. Codes used for the thermal bridges analysed.

| Thermal bridges analysed                                      | Code for the classical roof | Code for the extensive green roof | Code for the semi-intensive green roof | Code for the intensive green roof |
|---------------------------------------------------------------|----------------------------|-----------------------------------|---------------------------------------|----------------------------------|
| The exterior wall intersection with the roof slab (attic)    | 1(a)                       | 1(b)                              | 1(c)                                  | 1(d)                             |

![Diagram 1(a)]

![Diagram 1(b)]

![Diagram 1(c)]

![Diagram 1(d)]

### Table 9. Codes used for the thermal bridges analysed.

| Thermal bridges analysed                                      | Code for the classical roof | Code for the extensive green roof | Code for the semi-intensive green roof | Code for the intensive green roof |
|---------------------------------------------------------------|----------------------------|-----------------------------------|---------------------------------------|----------------------------------|
| The filled interior wall intersection with roof slab         | 2(a)                       | 2(b)                              | 2(c)                                  | 2(d)                             |

![Diagram 2(a)]

![Diagram 2(b)]

![Diagram 2(c)]

![Diagram 2(d)]
Table 10. Codes used for the thermal bridges analysed.

| Thermal bridges analysed | Code for the classical roof | Code for the extensive green roof | Code for the semi-intensive green roof | Code for the intensive green roof |
|--------------------------|-----------------------------|-----------------------------------|----------------------------------------|----------------------------------|
| The empty interior wall intersection with roof slab | 3(a) | 3(b) | 3(c) | 3(d) |

![Diagram of 3(a)](image1)

![Diagram of 3(b)](image2)

![Diagram of 3(c)](image3)

![Diagram of 3(d)](image4)

Table 11. Codes used for the thermal bridges analysed.

| Thermal bridges analysed | Code for the classical roof | Code for the extensive green roof | Code for the semi-intensive green roof | Code for the intensive green roof |
|--------------------------|-----------------------------|-----------------------------------|----------------------------------------|----------------------------------|
| The reinforced concrete beam intersection with roof slab | 4(a) | 4(b) | 4(c) | 4(d) |

![Diagram of 4(a)](image5)

![Diagram of 4(b)](image6)

![Diagram of 4(c)](image7)

![Diagram of 4(d)](image8)
3. Analyses and discussions

With the data presented in the previous parts of the paper, a comparative analysis of the thermal transfer was carried out. The most important coefficient in this analyse, the linear thermal transfer coefficient \( \psi \) is defined by being the surplus flow \( \Delta \phi \) transmitted by a linear bridge, and it is directly related with its length \( l \) and the thermodynamic driving force for the flow heat \( \Delta T \) [15].

Taking into account the defining relation of the linear thermal transfer coefficient was established the practical calculation relationship, the mathematic formula, given by equation (1) [15]:

\[
\psi = \frac{\phi}{\Delta T} \frac{B}{R}
\]

where \( \phi \) - thermal flow related to the surface having a width, \( B \) (m) and length \( 1 \)m, expressed in \( \text{W/m} \);

\( \Delta T \) – temperature difference, \( \Delta T = T_i - T_e \), expressed in °C or K;

\( T_i \) – interior temperature, expressed in °C or K;

\( T_e \) – exterior temperature, expressed in °C or K;

\( R \) – unidirectional thermal resistance, expressed in \( \text{m}^2 \text{K/W} \).

The thermal flow was obtained from the thermal bridges modeling in the automatic calculation program, RDM version 6.17. The specific unidirectional thermal resistance was established according to equation (2) [15]:

\[
R = \frac{1}{\alpha_i} + \sum \frac{d}{\lambda} + \frac{1}{\alpha_e}
\]

where \( \alpha_i \) – the convective and radiative heat transfer coefficient of the interior surface;

\( \alpha_e \) – the convective and radiative heat transfer coefficient of the exterior surface.

In the calculus are used the following values for \( \alpha_i, \alpha_e \) and for corresponding thermal resistance:

\[
\alpha_i = 8 \quad \alpha_e = 24 \\
R_i = 0.125 \quad R_e = 0.042
\]

The thermal resistance value for each roof was calculated and established according to the dimension of the layer (\( d \)) and the coefficient of thermal conductivity (\( \lambda \)) and there are presented in table 12.

**Table 12. The thermal resistance values.**

| Type of structure                        | \( R \) [m²K/W] |
|------------------------------------------|----------------|
| Structure of the classical roof          | 7.455          |
| Structure of the extensive green roof    | 9.195          |
| Structure of the semi-intensive green roof | 9.725   |
| Structure of the intensive green roof    | 11.055         |
| Structure of the exterior wall           | 5.106          |

The thermodynamic performance of each roof has been evaluated taking into account the unidirectional thermal resistance determined by calculus previously presented and the linear thermal bridges coefficients. The analysis for the thermal bridges was made in the program RDM 6.17.

Table 13 presents the values of linear thermal bridges coefficients for the exterior wall intersection with the roof slab (attic) based on the thermal properties used in calculus, the thermal flow \( \phi \), the temperature difference \( \Delta T \), the width of the thermal bridge \( B \) and the unidirectional thermal resistance \( R_{\text{element}} \) and the iso values of heat flow for each type of roof.

Table 14 presents the values of linear thermal bridges coefficients for the filled interior wall intersection with roof slab based on the thermal properties used in calculus, the thermal flow \( \phi \), the temperature difference \( \Delta T \), the width of the thermal bridge \( B \) and the unidirectional thermal resistance \( R_{\text{element}} \) and the iso values of heat flow for each type of roof.
Table 13. Linear thermal bridges coefficients, $\Psi$, exterior wall - roof slab (attic).

| Thermal bridge   | $\phi$ [W/m] | $\Delta T$ [°C] | B [m] | $R_{element}$ [m²K/W] | $\Psi$ [W/m²°C] |
|------------------|---------------|-----------------|-------|------------------------|-----------------|
| Thermal bridge 1(a) | 8.65          | 38              | 1.20  | 7.455                  | 0.066           |
| Thermal bridge 1(a) (wall) | 11.26         | 38              | 1.20  | 5.106                  | 0.0695          |
| Thermal bridge 1(b) | 7.70          | 38              | 1.20  | 9.195                  | 0.0721          |
| Thermal bridge 1(b) (wall) | 11.18         | 38              | 1.20  | 5.106                  | 0.0591          |
| Thermal bridge 1(c) | 7.33          | 38              | 1.20  | 9.482                  | 0.0695          |
| Thermal bridge 1(c) (wall) | 11.13         | 38              | 1.20  | 5.106                  | 0.0578          |
| Thermal bridge 1(d) | 6.85          | 38              | 1.20  | 11.055                 | 0.0717          |
| Thermal bridge 1(d) (wall) | 11.03         | 38              | 1.20  | 5.106                  | 0.0552          |

Table 14. Linear thermal bridges coefficients, $\Psi$, filled interior wall - roof slab.

| Thermal bridge   | $\phi$ [W/m] | $\Delta T$ [°C] | B [m] | $R_{element}$ [m²K/W] | $\Psi$ [W/m²°C] |
|------------------|---------------|-----------------|-------|------------------------|-----------------|
| Thermal bridge 2(a) | 6.78          | 38              | 1.340 | 7.455                  | -0.0013         |
| Thermal bridge 2(b) | 6.01          | 38              | 1.340 | 9.195                  | 0.0124          |
Table 15 presents the values of linear thermal bridges coefficients for the empty interior wall intersection with the roof slab based on the thermal properties used in calculus, the thermal flow (\( \phi \)), the temperature difference (\( \Delta T \)), the width of the thermal bridge (B) and the unidirectional thermal resistance (\( R_{\text{element}} \)) and the iso values of heat flow for each type of roof.

Table 16 presents the values of linear thermal bridges coefficients for the reinforced concrete beam intersection with the roof slab based on the thermal properties used in calculus, the thermal flow (\( \phi \)), the temperature difference (\( \Delta T \)), the width of the thermal bridge (B) and the unidirectional thermal resistance (\( R_{\text{element}} \)) and the iso values of heat flow for each type of roof.

**Table 15. Linear thermal bridges coefficients, \( \psi \), interior wall - roof slab.**

| Thermal bridge | \( \phi \) [W/m] | \( \Delta T \) [°C] | B [m] | \( R_{\text{element}} \) [m²K/W] | \( \psi \) [W/m²°C] | Iso values of heat flow |
|----------------|------------------|------------------|-------|----------------|------------------|----------------------|
| 2(c)            | 5.56             | 38               | 1.340 | 9.735          | 0.0086           |                      |
| 2(d)            | 4.89             | 38               | 1.340 | 11.055         | 0.0074           |                      |
Table 16. Linear thermal bridges coefficients, $\psi$, reinforced concrete beam - roof slab.

| Thermal bridge | $\phi$ [W/m] | $\Delta T$ [°C] | B [m] | $R_{\text{element}}$ [m²K/W] | $\psi$ [W/m²°C] | Iso values of heat flow |
|----------------|--------------|----------------|-------|-----------------------------|-------------------|--------------------------|
| Thermal bridge 4(a) | 13.57/2 =6.785 | 38 | 1.340 | 7.455 | -0.0011 |
| Thermal bridge 4(b) | 12.00/2 =6.000 | 38 | 1.340 | 9.195 | 0.0121 |
| Thermal bridge 4(c) | 11.01/2 =5.505 | 38 | 1.340 | 9.735 | 0.0072 |
| Thermal bridge 4(d) | 9.77/2 =4.885 | 38 | 1.340 | 11.055 | 0.0073 |

The results obtained for all four types of roof analysed show a positive influence in the case of all three types of green roof comparing with the classical roof. First, there is an improvement in the thermal resistance ($R_{\text{element}}$) increasing by 23% in the case of extensive green roof compared to the classical roof, from 7.455m²K/W ($R_c$) to 9.195m²K/W ($R_e$); increasing by 30% in the case of semi-intensive green roof compared to the classical roof, from 7.455m²K/W ($R_c$) to 9.735m²K/W ($R_s$); and increasing by 48% in the case of intensive green roof compared to the classical roof, from 7.455m²K/W ($R_c$) to 11.055m²K/W ($R_i$).

Secondly, there is a decreasing of the thermal flow ($\phi$): in the case of the first thermal bridge, the exterior wall intersection with the roof slab (attic), its value in the case of the classical roof is 8.65 W/m, while in the case of the green roofs it is 7.70 W/m, 7.33 W/m, 6.85 W/m. For the second thermal bridge, the filled interior wall intersection with roof slab, it is also remarked a positive influence, in the case of the classical roof, the value of the thermal flow it is 6.78 W/m, decreasing to 4.89 W/m in the case of the intensive green roof. The third thermal bridge, the empty interior wall intersection with the roof slab, also shows a decrease in the thermal flow from 6.78 W/m for the classical roof to 4.88 W/m for the intensive green roof. The last thermal bridge, the reinforced concrete beam intersection with the roof slab, also highlights the decreasing of the thermal flow noting its value for the classical roof, 13.57 W/m and its value for the intensive green roof 9.77 W/m, but in the calculus, it is taken half of the thermal flow for each roof.

4. Conclusions

In this paper, the benefits of the green roof as a technique of insulating the buildings were analysed taking into account the thermal resistance and the heat flow of the main types of green roof: extensive, semi-intensive and intensive, comparing them with the classical roof. Additionally, the structure of these four types of roof and the properties of the material were analysed, selected and used for the modeling of the thermal bridges, to evidence their capacity to influence the heat flow intensity. Taking
into account the complexity of this problem, the structural details, material properties, and thermal analyses were performed in thermal bridges utilizing the RDM 6.17 software.

Results from the thermal analyses show that there is an improvement for all three types of green roofs in terms of thermal resistance and thermal flow for all types of thermal bridges. These facts are supported by numerical results and modeling in the program.

Even if the positive influence of the green roof systems, in all three structures, is sustained by the values of the thermal resistance and the values of the thermal flow, the very large differences between thermal resistances values are not balanced by the values of the thermal flow. Therefore, an increase in the linear thermal bridge coefficients ($\psi$) is noted.

The calculations were carried out following Normative Regarding the Calculation of Thermic Properties of Building Construction (C 107-2005), but as future research, it is proposed to balance the two terms, the thermal resistance, and the thermal flow, and restore the calculations according to ISO.

In conclusion, the unpredictable results obtained for the analysed thermal parameters let conclude that, although there is no well-determined thermo-technical advantage for all three types of green roof systems, anyhow, these solutions represent a technology with favourable environmental impact, in terms of both sustainability and aesthetics.

5. References
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