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Research paper

TYPICAL THERMAL BRIDGES IN LARGE-PANEL PREFABRICATED RESIDENTIAL BUILDINGS OF THE OS-68-GL SYSTEM

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Abstract

This paper presents the results of a thermal assessment and diagnostics of the façade elements of a large-panel prefabricated residential building located in Sofia, Bulgaria. The investigated structure is a representative example of buildings constructed using the OS-68-GL system, which has traditionally been used for various types of dormitories. The investigation was carried out using infrared thermography, with surface temperatures measured both externally and internally on the façade elements, including prefabricated panels and monolithic basement walls. Based on the analysis of the results, conclusions were drawn regarding the presence of areas of increased heat transfer and thermal bridges.

It was established that, in buildings of this type, characteristic thermal bridges occur along the perimeter of blind façade panels (without openings), where no intermediate thermal insulation layer is incorporated into the panel. Thermal bridges were also identified at the horizontal and vertical joints between the façade panels and in the areas of the balconies. Façade panels containing window and door openings, as well as spandrel panels (beneath windows), are also characterized by significant heat transfer. In addition, the building's window and balcony door systems are in unsatisfactory condition, resulting in substantial heat losses through these elements.

The obtained results could serve as a basis for further detailed investigations, including the determination of heat transfer coefficients for the identified building elements. These data could subsequently be used to support the design and implementation of energy renovation measures for buildings of this type.

Key words: l*arge-panel prefabricated residential buildings, thermal bridges, infrared thermography*

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1. INTRODUCTION

The construction of large-panel residential buildings (LPRBs) in Bulgaria has a history of more than 60 years. Following the experimental stage, the period from 1965 to 1975 marked the beginning of the large-scale construction of buildings using industrial technologies and the comprehensive industrialization of the construction sector. As a result of the policies implemented and the production activities of the prefabricated housing construction plants, to date, 860 000 panel dwellings have been constructed in the Republic of Bulgaria, distributed among 18 900 large-panel residential buildings, with 82,3% of LPRBs located in cities serving as regional administrative centers [1]. Some of the most widely used systems for this type of building in Sofia are the BS-69-SF and BS-69-SF-UD systems, with buildings constructed using these systems accounting for approximately 71% of all LPRBs in the city [2]. To meet the demand for student and workers' dormitories, a separate system, OS-68-GL, was developed [3]. As shown in *Figure 1*, LPRBs constructed using the OS-68-GL system were built predominantly during the period from 1968 to 1978.

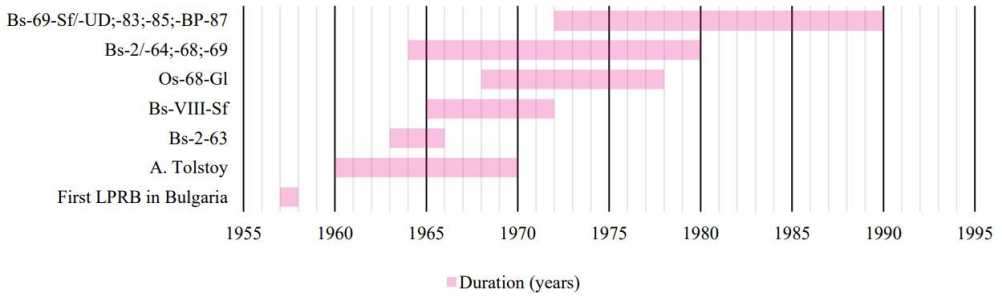


Figure 1. Timeline of LPRB construction periods by system in Sofia, Bulgaria [4]

Current trends are focused on the renovation of large-panel residential buildings (LPRBs) [5], the implementation of measures to improve their energy efficiency [6–9], and the modernization of their building services [10]. Renovation should be carried out on the basis of a detailed evaluation of the serviceability of these buildings, based on both a structural investigation involving destructive and non-destructive testing [11,12] and a thermal performance assessment [13].

According to the current regulatory framework in Bulgaria, and more specifically Ordinance No. 5 on the Technical Passports of Constructions [14], technical passports are required to be prepared for all existing constructions. An important stage in the preparation of technical passports is the structural assessment and the evaluation of energy performance. Similar regulatory requirements exist in other countries, and the data collected and analyzed through the technical passporting process can be used to assess the reliability of buildings [15]. The thermal insulation measures and insulation systems of LPRBs should be designed taking into account the results of the thermal performance assessment conducted for the building and, accordingly, the recommendations documented in the building's Technical Passport.

Also, according to the Energy Efficiency Act in Bulgaria [16], an energy audit must be carried out for all existing buildings, resulting in a report and an energy performance

certificate. The energy audit must determine the thermal performance characteristics of the building and its building elements. Following reconstruction or renovation of the building, the energy performance certificate must be updated.

This paper presents the results of a thermal performance assessment and infrared thermographic investigation of selected facade elements of an LPRB constructed using the OS-68-GL system and located in Sofia, Bulgaria, with the aim of identifying typical thermal bridges. The obtained results may be considered preliminary and could serve as a basis for more detailed investigations at a later stage, which may supplement and further develop the findings, including the determination of heat transfer coefficients to be used in the design and energy renovation of buildings.

2. MATERIALS AND METHODS

2.1. General characteristics of the investigated building

The building investigated in this study is a student dormitory constructed using the OS-68-GL system and located in the Studentski Grad district of Sofia, Bulgaria. It is part of the earlier development of the complex and is a large-panel residential building dating from 1977. The OS-68-GL system was developed based on precast reinforced concrete panels originally designed for frameless-panel residential buildings, with axes spaced at 3,60 m and 5,10 m in plan and a floor-to-floor height of 2,80 m. The system was primarily used for the construction of dormitories ranging from four to eight storeys. The building has a frameless structure consisting of wall and floor panels, with a gross floor area (GFA) of 8334,37 m² and a building footprint of 1177,82 m². A general perspective and plan view of the building are shown in *Figure 2*.



a) *b)*

Figure 2. General view of the building: a) perspective; b) plan [17]

The blind façade panels (panels without openings) are made of three-layer reinforced concrete with an intermediate layer of expanded polystyrene (EPS), while the façade panels with window and door openings are made of expanded clay perlite concrete, and the spandrel panels (panels beneath the window openings) are made of ordinary reinforced concrete [3]. Some of the main characteristics of the façade elements of buildings constructed using the OS-68-GL system are presented in *Table 1*.

Table 1. Characteristics of façade elements of buildings constructed using the OS-68-GL system, based on [3] and [18]

№	Façade element	Element type	Thickness, cm	Main characteristics
1	Basement reinforced concrete walls	Monolithic reinforced concrete	40 cm	Ordinary concrete, grade M 200 (approximately Class C12/15)
2	Façade panels without openings along the end transverse axes of the building (blind panels)	Precast panels	20 cm	Three-layer panels made of ordinary reinforced concrete with an intermediate 5 cm thick EPS layer
3	Façade panels with window and door openings	Precast panels	20 cm	Single-layer panel made of expanded clay perlite concrete, grade M75
4	Spandrel panels (panels beneath the window openings)	Precast panels	20 cm	Ordinary concrete, grade M 200 (approximately Class C12/15)
5	Elements between window openings (inter-window elements)	Layer-by-layer assembly	7 cm	Consist of a wooden board on the exterior side, a 40 mm thick mineral wool layer in the middle, and a wooden board on the interior side

2.2. Research methodology

The identification of characteristic thermal bridges along the building façade was carried out using infrared thermography. The use of a thermal imaging camera for building diagnostics enables the visualization of energy losses, detection of missing or defective insulation, identification of moisture in insulation, roofs, and walls, and localization of thermal bridges, among other applications [19]. The method can be successfully applied to both insulated and uninsulated façades [20,21].

In this study, a FLIR i7 thermal imaging camera was used, with the following technical characteristics: thermal sensitivity of 0,1 ℃, image resolution of 140×140 pixels, spectral range of 7,5–13 μm, temperature range from -20 ℃ to +250 ℃, and accuracy of ±2% [22].

The procedure for detection of thermal bridges in this study is outlined below:

- a visual inspection and an overall digital photograph of the façade were taken;
- an overall thermographic image of the same façade was obtained using the FLIR i7 thermal imaging camera to visualize areas with different surface temperatures;
- detailed thermographic imaging was performed on the areas where higher surface temperatures, indicative of thermal bridges, were identified, from the exterior side of the building;
- the same areas were imaged from the interior side of the building.

The time interval between the capture of the internal and external images was a maximum of 15 minutes. A general view of the building, including the areas selected for detailed infrared thermographic measurements, is presented in *Figure 3*.

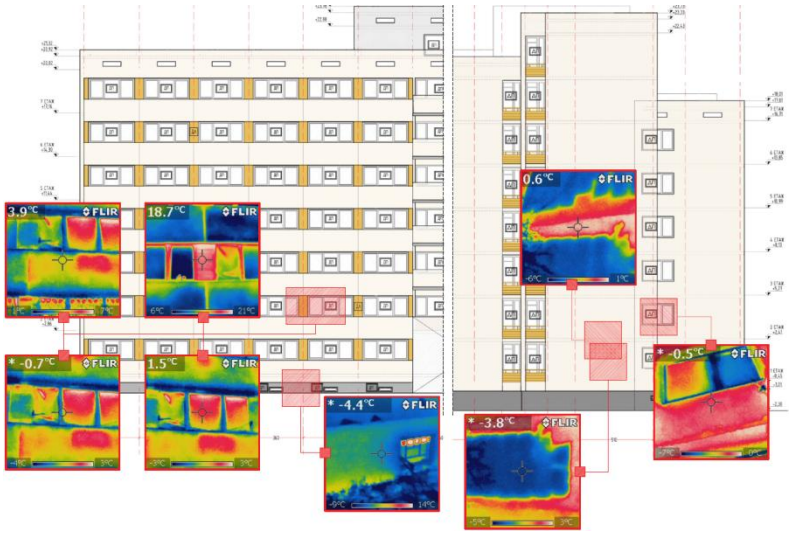


Figure 3. Areas of the building selected for detailed infrared thermographic measurements. Source: Authors

3. RESULTS AND DISCUSSION

Following the initial comprehensive visual inspection of the building façades, detailed infrared thermography was performed on a façade panel incorporating a thermal insulation layer, examined both in the insulated area and in the area without thermal insulation. The investigation also included a façade spandrel panel beneath a window, an inter-window timber element, a façade panel with a window opening and without a thermal insulation layer, and a monolithic reinforced concrete basement wall. It should be noted that the thermographic images of the façade elements on the second floor were captured from ground level.

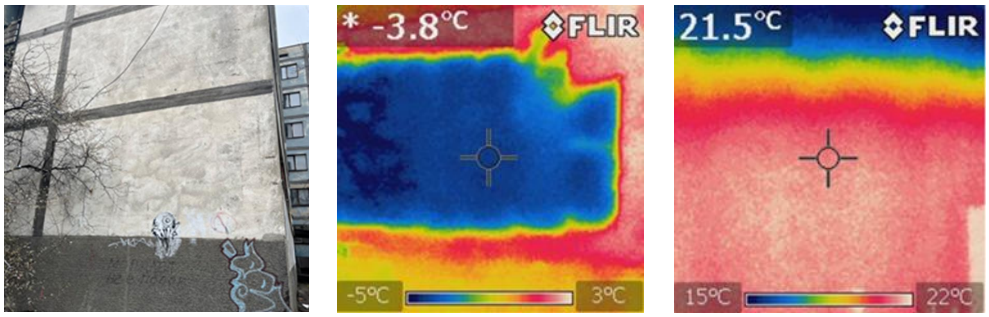
The thermographic investigation was conducted on 16 February 2023, during the period from 09:00 to 11:00. As the aim of the study is to provide a preliminary qualitative assessment of thermal bridges, measurements of humidity and air velocity were not performed.

Table 2 below and the thermographic images summarize the results obtained from the investigation of selected characteristic building elements. The measured surface temperatures on the internal and external sides of the elements are presented.

Table 2. Measured internal and external surface temperatures of the façade elements

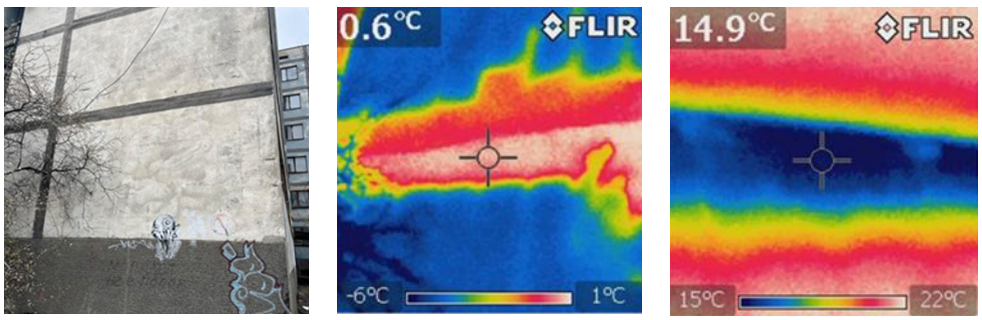
№	Façade element	Internal surface temperature, °C	External surface temperature, °C
1	Façade panel without openings along the end transverse axes of the building (blind panel)		
	a) in the area of the thermal insulation layer	21,5	-3,8
	b) in the area without the thermal insulation layer	14,9	0,6
2	Façade panel with a window opening	9,4	-0,5
3	Spandrel panel	19,5	3,9
4	Inter-window element	26,9	18,7
5	Basement reinforced concrete wall	7,0	-4,4

The digital and thermographic images of the façade elements listed in *Table 2* are presented in the figures below. Each figure includes a digital photograph of the investigated element and thermographic images taken from the exterior and the interior.



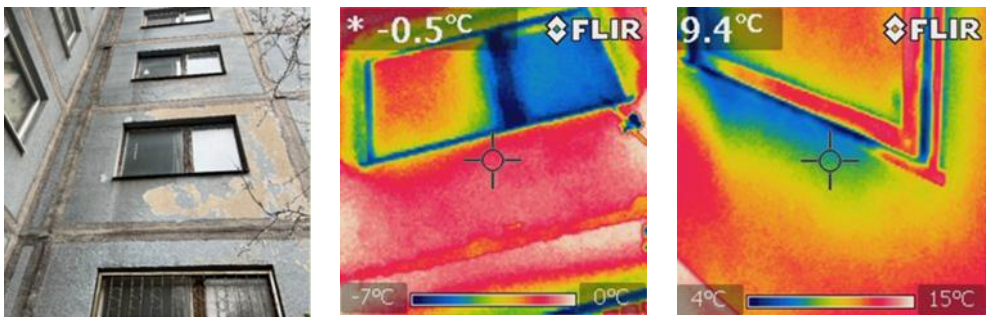
a) *b)* *c)*

Figure 4. Digital photograph and thermographic images of the façade panel without openings along the end transverse axes of the building (blind panel), in the area of the thermal insulation layer: a) digital photograph; b) exterior thermographic image; c) interior thermographic image. Source: Authors



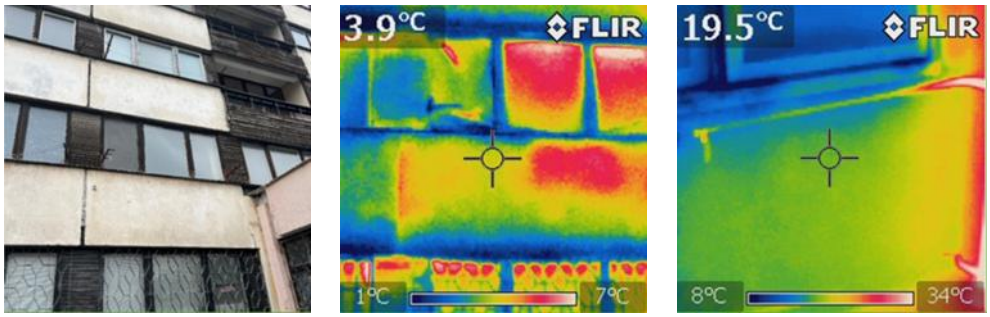
a) *b)* *c)*

Figure 5. Digital photograph and thermographic images of the façade panel without openings along the end transverse axes of the building (blind panel), in the area without the thermal insulation layer: a) digital photograph; b) exterior thermographic image; c) interior thermographic image. Source: Authors



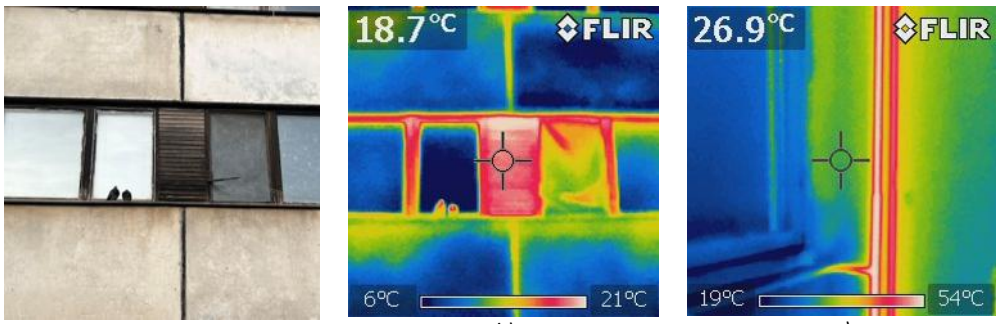
a) *b)* *c)*

Figure 6. Digital photograph and thermographic images of the façade panel with a window opening: a) digital photograph; b) exterior thermographic image; c) interior thermographic image. Source: Authors



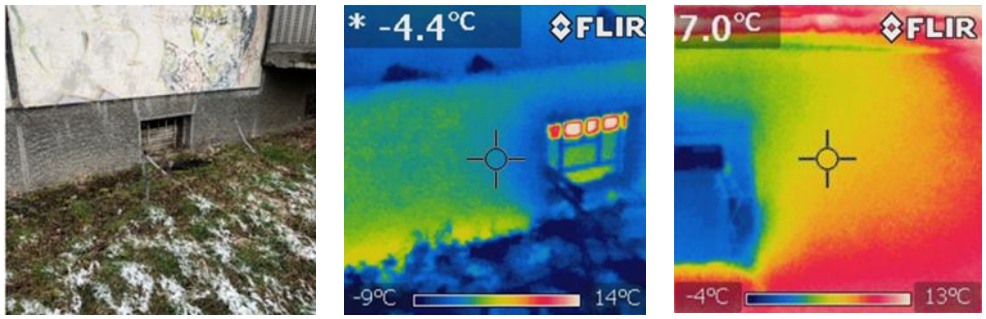
a) *b)* *c)*

Figure 7. Digital photograph and thermographic images of the spandrel panel: a) digital photograph; b) exterior thermographic image; c) interior thermographic image. Source: Authors



a) *b)* *c)*

Figure 8. Digital photograph and thermographic images of the inter-window element: a) digital photograph; b) exterior thermographic image; c) interior thermographic image. Source: Authors



a) *b)* *c)*

Figure 9. Digital photograph and thermographic images of the basement reinforced concrete wall: a) digital photograph; b) exterior thermographic image; c) interior thermographic image. Source: Authors

The results presented in *Table 2*, together with those shown in *Figures 4–9*, indicate the presence of areas of significant heat transfer and thermal bridges in the façade elements of the building. For example, in the façade panel without openings along the end transverse axes of the building (blind panel), the temperature difference between the internal and external surfaces in the area with the incorporated thermal insulation layer is approximately 25,3 °C. In the same panel, but in the area without the thermal

insulation layer, the temperature difference between the two surfaces (internal and external) is approximately 14,3 °C. The thermographic images presented in *Figures 4* and *5* clearly show the area with the thermal insulation layer and the characteristic thermal bridge outside this area.

A temperature difference of a similar magnitude (approximately 15,6 °C) is also observed between the internal and external surfaces of the spandrel panel. These values are consistent with the fact that both panels are made of ordinary concrete and have a thickness of 20 cm. The poor thermal performance of the spandrel panel can also be inferred from the higher-temperature area visible on its external surface, corresponding to the location of a heating radiator belonging to the building's heating system (see *Figure 7b*).

For façade panels with window openings, the differences between the measured surface temperatures are smaller, at approximately 10 °C. This can be attributed to the lower heat transfer coefficient of this type of panel, which is made of expanded clay perlite concrete. A characteristic linear thermal bridge is also observed at the joints between the panels. Similar characteristic linear thermal bridges are observed at the vertical joints between the spandrel panels.

Areas of significant heat transfer are also observed at the inter-window elements (see *Figure 8*) and at the monolithic reinforced concrete basement walls (see *Figure 9*). Despite the presence of a 40 mm thick thermal insulation layer within the inter-window element, a relatively high temperature is observed on its external surface, which may be attributed to compromised integrity of the thermal insulation.

Based on an analysis of the structure of the various façade elements (see *Table 1*) and the thermographic results, it can be concluded that the main reasons for the differences in external surface temperatures are the characteristics of the façade elements and, consequently, the different values of their heat transfer coefficients.

Although not presented in detail in this paper, thermal bridges were also identified at the internal corners between the façade panels and in the balcony areas. These findings indicate that, in future energy renovation of buildings of this type, specific measures for the installation of effective thermal insulation systems should also be considered for these elements.

Since the measurements refer only to individual façade elements, the relationship between the measured temperatures and the numerical data used for energy efficiency and thermal performance calculations has not been determined. It is therefore planned to investigate this relationship more comprehensively by assessing a larger number of elements of the same type under comparable conditions.

4. CONCLUSIONS

This paper presents the results of an infrared thermographic investigation of the façade elements of a large-panel residential building constructed using the OS-68-GL system and located in Sofia, Bulgaria. Based on the measured surface temperatures on the internal and external sides of the façade elements, areas of significant heat transfer and characteristic thermal bridges were identified.

It was established that, in buildings of this type, characteristic thermal bridges occur along the perimeter of blind façade panels, in areas where no intermediate thermal insulation layer is incorporated, at the horizontal and vertical joints between façade panels with openings, at the vertical joints between spandrel panels, and at other locations. Façade panels with window openings, spandrel panels, as well as monolithic basement reinforced concrete walls, are also characterized by significant heat transfer.

The results indicate that specific measures should be taken to implement effective thermal insulation systems in future energy renovation of buildings of this type.

The present study provides an preliminary qualitative assessment rather than a complete assessment of the thermal performance of buildings of this type. Directions for future research include a comprehensive and detailed thermographic investigation of all building envelope elements, aimed at quantitatively evaluating their thermal performance and determining the overall heat transfer coefficients based on established methodologies [21,23]. The overall heat transfer coefficients determined in this way could be effectively used in the design of energy efficiency measures and the energy renovation of buildings.

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