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# The First International Students Scientific Conference
# "MULTIDISCIPLINARY APPROACH TO CONTEMPORARY RESEARCH"

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# INFRARED-THERMOGRAPHY BASED THERMAL ANALYSIS OF THE OLD VS. NEW TYPE OF THE NON-RESIDENTIAL BUILDING CONSTRUCTION AT THE IDENTICAL GEO-LOCATION AND ORIENTATION

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**Abstract:** *IRT methodology was used in this research in order to provide critical review on thermal behavior of two non-residential buildings constructions at the same geo-location and orientation. Faculty of Agriculture (University of Belgrade, Serbia) headquarters old and new facilities were used as research objectives. IRT methodology showed the differences in thermal behavior of old and new building envelopes. This results shows that new building has slightly worse insulation properties and higher heat losses. The calculation results showed that the specific heat flow rate through the old building envelope was 6.76 W/m2, and the specific heat flow rate through the new building envelope was 15.18 W/m2.*

Key words: Infrared-thermography, buildings, materials, energy, efficiency.

## 1. INTRODUCTION

Infrared-thermography (IRT) provides not just an image, but the temperature data for each measurement point within the image [1, 2]. IRT methodology application provides large amounts of data and allows many different ways of results interpretation [3]. In this research, IRT methodology [4] was used to provide useful information regarding the two types of façade's wall construction non-residential building constructions at identical geo-location. In accordance with the gathered IRT data and project documentation, buildings envelope thermal behavior was analyzed in order to explore the benefits and faults of each construction approach and to justify the choice of used materials [5, 6]. This research was conducted during the school year 2016/17 as a part of a course of "Thermodynamics and Thermo-technics" at the Institute of agricultural engineering, Faculty of Agriculture – University of Belgrade, Serbia.

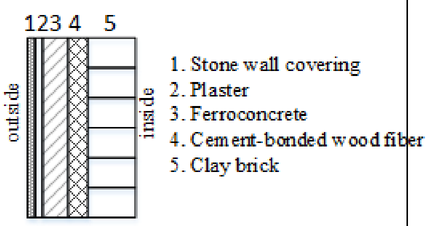
## 2. MATERIALS AND METHODS

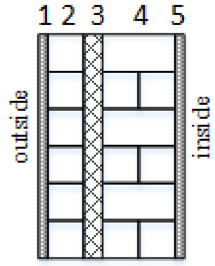
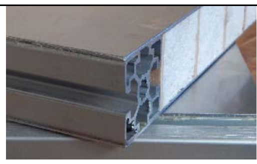
Faculty of Agriculture (University of Belgrade) building (44°50'25.68"N; 20°24'43"E) is located in Zemun municipality, of the Serbian capital city Belgrade. It consists of two parts (old and new building) which rely on one another (Fig.1). The old building was constructed during the period 1927-1932 in the style of neoclassical architecture. In its purest form it is a style principally derived from the architecture of classical antiquity, very popular in late 18th, 19th and in the first half of 20th century. Neoclassicism also influenced city planning and many other non-residential buildings projects. In 1972 the capacities of old building were extended by constructing the new and modern building part of the faculty facility. The new part was designed to cover all needs for educational work (conference rooms, classrooms, computer center, library, etc.) and scientific work (laboratories, offices and cabinets).

**Figure 1:** Faculty of Agriculture headquarters (old and new building)

The differences between these two types of building constructions are obvious and can be observed from the technical and architectural main project documentation, as well as from visual inspection and simple non-destructive measurements. Comparative characteristics are provided in Table 1.

**Table 1**: Old and new building comparative information

| Building | Old | New |
|---|---|---|
| Exposed wall | **Solid wall** | **Solid wall**<br><br>Thermal conductivity: 1.46 W/mK<br>Thickness: 0.25 m |
| | | **Panel wall** |

| | | | |
|---|---|---|---|
| | |  <br>1. Plaster<br>2. Full brick<br>3. Glass wool<br>4. Full brick<br>5. Plaster<br>Thermal conductivity:<br>0.62 W/mK<br>Thickness: 0.60 m | <br>Material: Insulated aluminum metal panel<br>Thermal conductivity:<br>0.63 W/mK<br>Thickness: 0.08 m |
| Window | joinery |  |  |
| | materials | glass + wood | glass + aluminum metal |
| | glass quality | clear, 4 mm | toned, 15%, 4 mm |
| | glazing | secondary, 1+1, | double, 8 mm cavity |
| | thermal conductivity | 2.8 W/mK | 3.1 W/mK |

In accordance with the main architectural project documentation, 3D building model was developed (Fig.2) and used for further building envelope analysis, especially during the areas calculations. The building was monitored during the soft winter period, and the outdoor air temperature was measured +5°C. The central heating system was operational during the measurements and the indoor temperature was found to be +19°C.


**Figure 2:** 3D model of Faculty of Agriculture building envelope

Infrared-thermography (IRT) recording was performed on a dry and cloudy weather conditions, in the late afternoon hours (16:00) at the end of a work week (Friday), so it may be presumed that monitored building outdoor surfaces (north side) was captured in stationary temperature behavior and without the influence of the sunshine. The recording was performed with Fluke Ti110 IR camera (R:P=295:1; temperature range -20÷250°C; accuracy ±2°C; resolution 0.08°C). Indoor and outdoor air temperatures were measured with laboratory glass thermometers with mercury.

## 3. RESULTS AND DISCUSSION

IRT measurement results was compared for simultaneously captured old and new building envelope (Fig.3). The comparison areas was 50 m$^2$ on old and the same area on new building (boxes are highlighted on Fig.3). The average temperatures in these areas were captured to be +8.1°C on old and +8.6°C on new building. Solid wall surface temperatures maximum values on the old building were in range 9 ÷ 9.8°C, and on the new building temperatures maximums were in ranges 8 ÷ 9°C for stone wall and 9.7 ÷ 10.4°C. Over all surface temperatures (window glass included) were in range: 6.6 ÷ 9.8°C for old building and 7.1 ÷ 11.8°C for new building. This results shows that new building has slightly worse insulation properties and higher heat losses. Heat flow rate was calculated with the Eq.1.

$$q = A \cdot \Delta T \cdot \frac{\lambda}{\delta} \quad [W] \tag{1}$$

where: λ – thermal conductivity of exposed wall, W/mK; A – area, m$^2$; ΔT – temperature difference of exposed wall inside and outside surface. The used overall average values of temperature differences between inside and outside wall surface were: for old building ΔT=10.9°C and for new building ΔT=10.4°C. The both buildings envelopes were exposed to the same outdoor conditions, due to the exact same orientation (north) and equal height of the monitored envelope area. Therefore, it may be assumed that the convection heat losses from the outside wall surfaces to the surrounding air were carried out under the same external conditions. Thermal conductivity of the exposed wall was calculated for wall structures described in Table 1. The calculation results showed that the specific heat flow rate through the old building envelope was 6.76 W/m$^2$, and the specific heat flow rate through the new building envelope was 15.18 W/m$^2$.

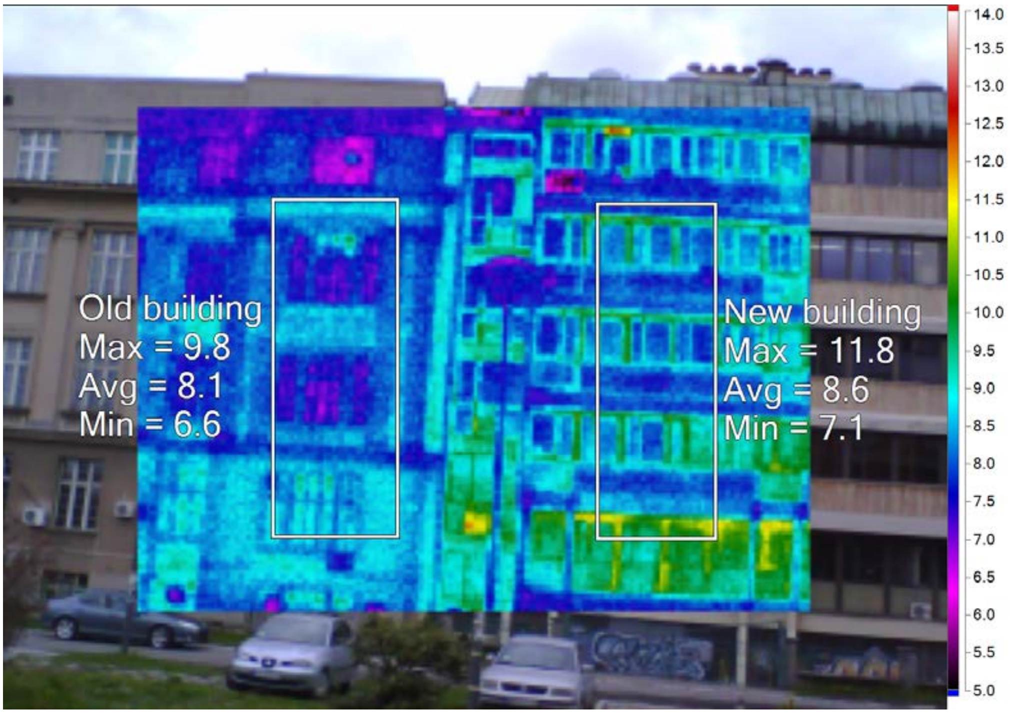



**Figure 3:** IRT image comparative review of old and new building surface temperatures

The temperature histogram (Fig.4) confirms that new building is losing heat more intense than the old one. Histograms shows the isothermal distribution and representation of the individual temperature values, measured on outside surface of the wall on the observed area of 50 m2. The widest temperatures range in new building histogram shows that there was a variety of used materials. It is evident that, across the range, all new building surface temperature values were evenly represented, opposed to the values of the old building. Captured surface temperatures of old building are average lower than one of the new building for approximately 0.5 ÷ 2°C.

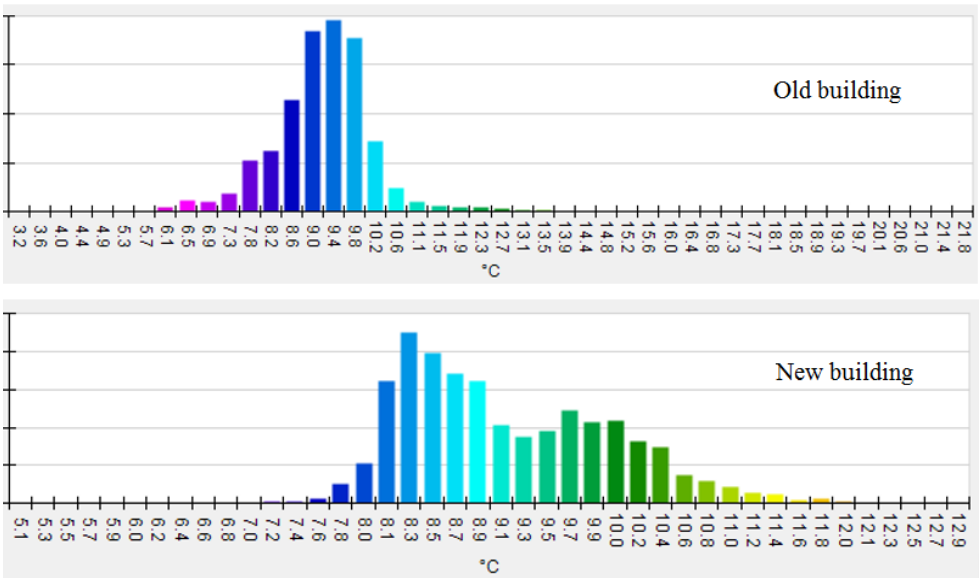



**Figure 4:** Old and new building outdoor surface temperature histogram

According to the 3D-IRT diagram (Fig.5), the hottest areas are on new building joineries, meaning that those surfaces are the one with the biggest heat losses. The combination of metal joinery and metal panels appears to be highly ineffective in preventing the heat leaving the building. Red and yellow peaks on new building 3D-IRT diagram are positioned in places of thermal bridge effect appearances. These temperature maximums can be explained with the fact that metal materials have higher values of thermal conductivity than wood.

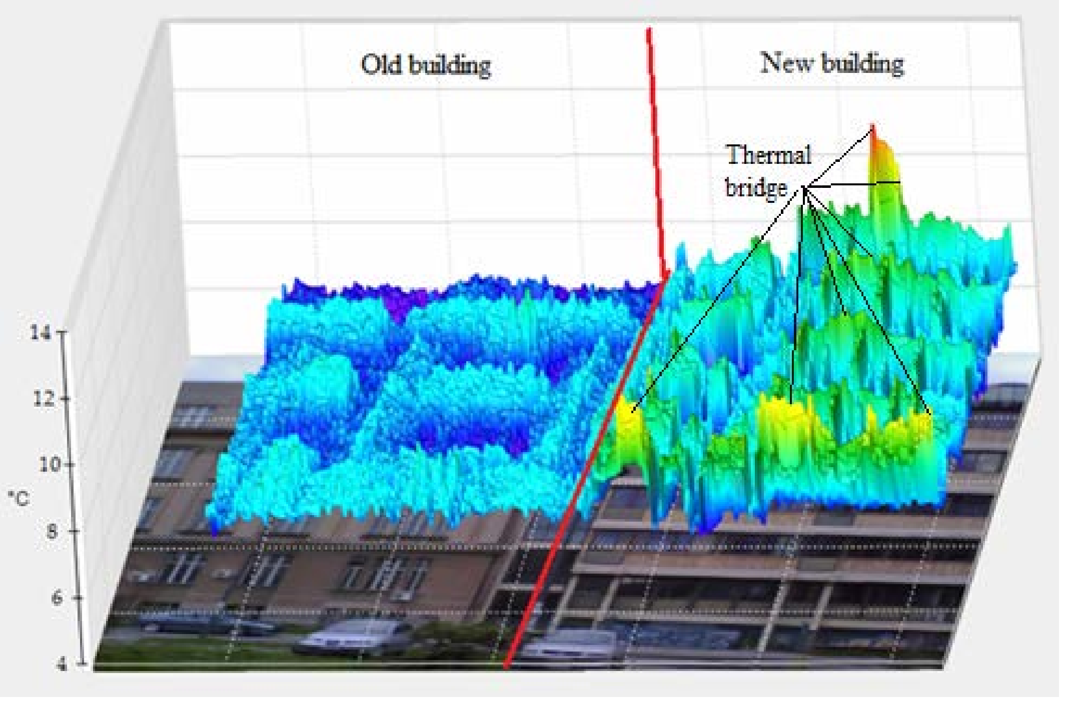



**Figure 5:** 3D-IRT diagram of building outdoor surface temperatures

## 3. CONCLUSION

IRT methodology was used in this research in order to provide critical review on thermal behavior of two non-residential buildings constructions at the same geo-location and orientation. Faculty of Agriculture (University of Belgrade, Serbia) headquarters old and new facilities were used as research objectives. IRT methodology showed the differences in thermal behavior of old and new building envelopes.

Results were in favor on old building construction style and choice of built in materials. The specific heat flow rate through the old building envelope was 6.76 W/m2, and the specific heat flow rate through the new building envelope was 15.18 W/m2. The new building has greater heat losses because of the large areas made of metal thermal insulation panels. The aluminum metal joinery that were used on new building are highly ineffective, contributing the bigger loss of heat.

Future research would be oriented towards the analysis of potential cost effective improvements of ineffective building surfaces and joineries, and their thermal properties.

## 4. ACKNOWLEDGEMENT

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## REFERENCES

[1] Ascione, F., Ceroni, F., De Masi, R.F., F.de' Rossi, Pecce, M.R.: Historical buildings: Multidisciplinary approach to structural/energy diagnosis and performance assessment, Appled Energy, 2015. (doi: 10.1016/j.apenergy.2015.11.089)

[2] D. González-Aguileraa, S. Lagüelab, P. Rodríguez-Gonzálveza, D. Hernández-Lópezc: Image-based thermographic modeling for assessing energy efficiency of buildings facades, Energy and buildings, Vol. 65, pp. 29-36, 2013. (doi: 10.1016/j.enbuild.2013.05.040)

[3] C.A. Balaras, A.A. Argiriou: Infrared thermography for buildings diagnostics, Energy and buildings, Vol. 34, pp. 171-183, 2002.

[4] A. Kylili, P.A. Fokaides, P. Christou, S.A. Kalogirou: Infrared thermography (IRT) applications for building diagnostics: A review, Applied Energy, Vol. 134, pp. 531–549, 2014.

[5] M. Fox, D. Coley, S. Goodhew, P.deWilde: Thermography methodologies for detecting energy related building defects, Renewable and Sustainable Energy Reviews, Vol. 40, pp. 296–310, 2014.

[6] E. Barreira, V.P. de Freitas: Evaluation of building materials using infrared thermography, Construction and Building Materials 21, pp. 218–224, 2007.