Quantitative Infrared Thermography for Thermal Transmittance of Historic Building Envelopes: A Review of Calculations and Prospects for Innovative Approaches

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Buildings account for one-third of global energy consumption and are responsible for a quarter of carbon dioxide emissions. In Europe, the building sector accounts for 40% of the EU's total energy consumption, 35% of the buildings are more than 50 years old, and almost 75% are energy inefficient . Considering that more than 60% of world historical constructions is located in Italy, the optimization of the energy efficiency of this architectural heritage is very important. The goal of the energy-efficient building concept is to provide a highly energy-efficient and decarbonized building complex. In this regard, the thermophysical properties of building components are key factors to consider. The thermal transmittance (U-value) has become a key parameter for assessing the thermal quality of the building envelope and steady-state heat transmission performance.

The U-value is based on international standards, in particular it is possible to calculate the design value with ISO 6946 or by in situ measurements, using a flow meter following recommendations foreseen in ISO 9869. The heat flux meter (HFM) method is costly and time-consuming for in-situ thermal transmittance measurements, which can be affected by thermal bridging, shielding or variation of temperature gradient, especially for historic buildings. Infrared thermography (IRT) has been widely used in buildings in the past 40 years, and IRT is commonly used as a qualitative analysis to determine building defects visually. Quantitative infrared thermography (QIRT) has received more attention from scholars during the last 20 years. QIRT for assessing building envelope U-values dates back to Madding's[1] study and is expected to be a promising alternative to the HFM method. It is worth noting that drones are given more opportunities to perform U-value assessments with the advantage of accessing data and conducting research without physical intervention. Although many scholars have tried to calculate the U-value based on QIRT of drones, the formulation of relevant standards and innovative procedures is still the direction and outlook for future research.

This paper aims to provide a detailed review of the use of QIRT for historic building envelope thermal transmittance assessment by drawing from an extensive bibliography, with particular emphasis on the discussion of the range of deviation and validity of the various U-value formulas[1–5] based on the QIRT, as well as the effect of convective heat transfer coefficients in the QIRT on the assessment of the U-value[6]. In addition, artificial intelligence represented by machine learning algorithms for the calculation and prediction of thermal transmittance of historic building envelopes will be discussed and foregrounded, especially the case of the combination of artificial neural networks and drones[7].

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