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Finite Element Analysis of Thermal Bridges in Mediterranean Residential Building Using Iot-Based Temperature Monitoring

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Abstract

Thermal bridges are localized regions of increased heat transfer that reduce the thermal efficiency of building envelopes and contribute to higher energy consumption. This study presents a three-dimensional finite element model (FEM) to investigate the thermal performance of a representative Mediterranean residential building using realistic boundary conditions obtained from in-situ monitoring. An IoT-based sensing system continuously recorded indoor, outdoor, and surface temperatures over a seven-day period, and the measured data were incorporated into the numerical model. The FEM simulations evaluated temperature and heat flux distributions across the multilayer wall assembly, with particular attention to the wall-to-wall, wall-to-floor, wall-to-partition, and partition-to-floor junctions. The results revealed significant heat flux concentrations at structural junctions, confirming their role as critical thermal bridges responsible for increased heat losses. The proposed methodology demonstrates the effectiveness of combining IoT monitoring with high-resolution FEM simulations to identify thermal weak points and support the design of energy-efficient retrofit strategies for existing Mediterranean buildings.

Keywords: Thermal bridges; Finite Element Method; Building envelope; Heat flux; Temperature distribution; IoT monitoring; Thermal monitoring.

1. Introduction

The decarbonization of the building sector has become a central objective in global climate policies, as buildings account for a significant proportion of total energy consumption and associated greenhouse gas emissions. In Mediterranean regions, characterized by moderate winters and increasingly intense summer conditions, the thermal performance of building envelopes plays a decisive role in maintaining indoor comfort while limiting energy demand. Consequently, enhancing the efficiency of building envelopes has emerged as a key strategy for reducing operational energy use and supporting the transition toward low-carbon and sustainable built environments.

Despite improvements in construction techniques and insulation standards, thermal bridges remain a critical source of inefficiency in buildings (Curto et al., 2022). These localized zones of increased heat transfer typically occur at structural junctions, material discontinuities, or geometric irregularities within the envelope. Their presence disrupts the continuity of thermal resistance, leading to elevated heat losses, non-uniform temperature distributions, and increased risk of surface condensation. Beyond energy implications, these effects can negatively impact occupant comfort and contribute to long-term material degradation.

The relevance of thermal bridges is particularly pronounced in Mediterranean building stock, where a large proportion of existing constructions were developed prior to the implementation of modern energy efficiency regulations (A. Mobaraki et al., 2025). In such buildings, insufficient insulation continuity and outdated construction practices often result in significant thermal anomalies at junctions such as wall-to-wall, wall-to-roof, and wall-to-floor connections. Identifying and quantifying these weak points is essential for improving building performance and informing effective retrofit strategies.

A wide range of methodologies has been developed for the assessment of Building thermal (B. Mobaraki et al., 2021) and thermal bridge detection (Choi et al., 2022). These cost-effective techniques have been applied for both the small and full scale structures (Porras et al., 2025). Experimental approaches such as infrared thermography, heat flux measurements, and in-situ temperature monitoring are commonly used to detect and evaluate thermal anomalies performance (B. Mobaraki et al., 2023). Infrared thermography, in particular, has been widely adopted due to its ability to provide qualitative visualization of heat loss patterns. However, its accuracy is highly dependent on environmental conditions such as solar radiation, wind, and surface emissivity, which can limit its reliability in real-world applications. Heat flux meters offer quantitative measurements of thermal transmittance, but they require stable boundary conditions and extended monitoring periods, making them less suitable for dynamic environments. Similarly, contact-based temperature measurements provide limited spatial resolution and are often insufficient for capturing the complexity of heat transfer across entire building components.

To overcome these limitations, recent research has explored advanced data processing techniques and hybrid methodologies. For instance, signal processing approaches have been proposed to enhance the quality of infrared thermography data by reducing environmental noise and improving the detection of thermal anomalies (Polverino et al., 2025). Probabilistic frameworks have also been introduced to account for uncertainty in in-situ measurements, enabling more robust evaluation of thermal bridge performance under variable conditions. In addition, full-surface thermal mapping techniques have been developed to provide spatially continuous assessments of envelope performance, addressing the limitations of point-based measurements.

Complementing experimental approaches, numerical modeling has become an increasingly important tool for the analysis of thermal bridges. In particular, the Finite Element Method (FEM) has proven to be highly effective in simulating heat transfer in complex building geometries and heterogeneous materials. This technique has been applied to various fields of engineering including above sturctures (B. Mobaraki & Vaghefi, 2024) and underground structures (B. Mobaraki & Vaghefi, 2015). FEM allows for detailed representation of temperature fields and heat flux distributions, providing insights that are difficult to obtain through experimental methods alone. Previous studies have demonstrated the capability of FEM to accurately quantify thermal bridge effects and evaluate the impact of design modifications. For example, numerical analyses of residential buildings have shown that the application of external insulation systems can significantly reduce linear thermal transmittance and associated heat losses (Omle et al., 2023). Other investigations have highlighted the importance of considering multidimensional and transient heat transfer effects, which are often neglected in simplified analytical methods.

Moreover, recent developments have focused on integrating FEM with building energy simulation tools to improve the representation of thermal bridges at the whole-building scale. Such approaches enable more accurate prediction of energy demand and help reduce the discrepancy between simulated and actual performance, commonly referred to as the performance gap. However, despite these advancements, the accuracy of FEM-based analyses remains highly dependent on the correct definition of boundary conditions, material properties, and numerical parameters such as mesh size and discretization strategy. Inaccurate assumptions in these inputs can lead to significant deviations in predicted results, highlighting the need for careful model calibration and validation. This implies that the building construction material (e.g., concrete) properties must be accurately introduced in the model (Hosseinzadehfard & Mobaraki, 2025).

In the context of Mediterranean climates, there is still a need for detailed investigations that combine high-resolution numerical modeling with realistic boundary conditions to better understand the behavior of thermal bridges in existing buildings. In particular, the influence of modeling parameters on simulation accuracy, as well as the comparative performance of different types of junctions, remains insufficiently explored.

This study addresses these gaps by employing FEM-based digital modeling to analyze thermal bridge performance in a representative building envelope located in Barcelona. The research focuses on quantifying heat flux, temperature distribution, and linear thermal transmittance across key envelope junctions, while also evaluating the sensitivity of simulation results to boundary conditions and mesh configuration. By identifying critical areas of energy loss and assessing their relative impact, the study provides valuable insights for improving envelope design and supporting targeted thermal rehabilitation strategies in Mediterranean buildings.

2. Materials and Methods

The study was conducted on a residential building located in Barcelona, Spain, representative of typical Mediterranean construction practices. The building, approximately 15 years old, was constructed prior to the enforcement of the most recent energy efficiency regulations, making it suitable for the analysis of thermal bridge effects in existing building stock. The selected case study focuses on a vertical section of the building envelope, specifically a façade wall segment including a wall-to-wall junction, identified as a potential thermal weak point.

2.1 Monitoring Strategy and Data Acquisition

To capture the real thermal behavior of the building envelope, an in-situ monitoring campaign was carried out over a continuous period of seven days. The targeted wall was instrumented using a set of commercial sensors capable of recording temperature data at multiple points across the envelope. Both indoor and outdoor air temperatures, as well as surface temperatures at critical points along the wall section, were measured at 15-minute intervals.

The monitoring system was designed to ensure minimal disturbance to occupants while maintaining high temporal resolution. Sensor placement was carefully selected to avoid direct interference from localized heat sources or shading effects. Data quality was ensured through periodic validation checks and filtering of anomalous readings. The collected temperature data were subsequently used as boundary conditions and input parameters for the numerical simulations.

2.2. Building Envelope Characteristics

The analyzed wall is a typical multi-layered façade system commonly found in Mediterranean residential buildings. The total wall thickness is approximately 32 cm and consists of the following layers (from exterior to interior):

- External cement-based render (2 cm)
- Hollow clay brick masonry layer (14 cm)
- Air cavity (5 cm), partially ventilated
- Lightweight concrete block layer (8 cm)

- Internal gypsum plaster (3 cm)

Thermal conductivity values for each material were assigned based on standard literature values. The presence of the air cavity and discontinuities at the junction contribute to localized variations in thermal resistance, making the wall suitable for thermal bridge analysis.

2.3. Geometric Modeling and FEM Setup

The numerical analysis was performed using a three-dimensional FEM model representing a section of the façade wall, including the critical wall-to-wall junction. The geometry was discretized using unstructured triangular elements, which are well-suited for capturing complex geometrical features and material interfaces within multilayer assemblies. To accurately represent heat transfer phenomena, particularly in regions with high thermal gradients, a non-uniform mesh was adopted.

The global mesh size was initially defined as approximately 10 mm, while local mesh refinement was applied in the thermal bridge region (junction area), reducing the element size to 2–3 mm. This refinement improves the resolution of temperature gradients and heat flux variations in zones where thermal discontinuities are most significant. The final mesh consisted of approximately 25,000–40,000 elements, depending on the level of refinement.

To ensure the reliability of the numerical results, a mesh sensitivity analysis was conducted. Three levels of mesh density (coarse, medium, and fine) were evaluated, with characteristic element sizes of approximately 15 mm, 10 mm, and 3 mm in the critical regions. Key output parameters, including heat flux distribution and linear thermal transmittance, were compared across these configurations. The results showed that the variation between the medium and fine meshes was below 2%, indicating that mesh independence had been achieved. Therefore, the medium-refined mesh was selected as the optimal compromise between computational efficiency and numerical accuracy.

The governing heat conduction equation was solved under steady-state conditions, assuming isotropic and homogeneous material properties within each layer. Boundary conditions derived from in-situ measurements were applied to the internal and external surfaces. The FEM model was implemented using a commercial simulation platform, ensuring numerical stability and convergence. Table 1 presents the FEM discretization parameters and mesh sensitivity analysis adopted in the 3D numerical model.

Table 1. Discretization strategy and numerical setup of the 3D FEM simulations.

Parameter	Description	Value / Specification
Model type	Numerical approach	3D steady-state FEM
Element type	Discretization element	Tetrahedral elements
Mesh strategy	Mesh configuration	Non-uniform mesh
Global element size	Base mesh size across the domain	~15 mm
Local refinement (junction area)	Refined mesh size	3–5 mm
Boundary layer refinement	Near-surface refinement	Enabled
Total number of elements	Final mesh density	~150,000–300,000
Coarse mesh size	Sensitivity level 1	~25 mm
Medium mesh size	Sensitivity level 2	~15 mm
Fine mesh size	Sensitivity level 3	~5 mm
Convergence criterion	Medium vs fine variation	< 2%
Selected mesh	Chosen for simulation	Medium mesh
Governing equation	Heat transfer model	3D steady-state conduction
Material assumption	Material properties	Isotropic and homogeneous
Boundary conditions	Input source	In-situ temperature data

2.4. Boundary Conditions and Environmental Exposure

Boundary conditions for the FEM simulations were derived from the monitored temperature data. Indoor temperature was assumed to be relatively stable, with minor fluctuations, while outdoor conditions exhibited typical Mediterranean variability over the monitoring period.

The façade under study is oriented towards the southwest, resulting in significant solar exposure during the afternoon hours. Direct solar radiation was observed approximately between 13:00 and 18:00, contributing to increased external surface temperatures. Although the FEM analysis primarily considers conductive heat transfer, the influence of solar gains was indirectly incorporated through the measured surface temperature data used as boundary inputs.

Convective heat transfer coefficients for internal and external surfaces were assigned based on standard values from building physics guidelines.

The monitoring campaign followed specific criteria to ensure reliability and relevance of the collected data:

- Continuous measurement over a representative period (7 days) to capture daily thermal cycles
- High-frequency data acquisition (10-minute intervals) to reflect transient behavior
- Selection of stable periods for simulation input to approximate quasi-steady-state conditions
- Filtering of outliers and sensor drift to improve data quality

The recorded temperature profiles were processed and averaged over selected time windows to define consistent boundary conditions for FEM simulations. Particular attention was given to periods with minimal environmental disturbances, ensuring that the numerical analysis reflects realistic but controlled thermal conditions.

3. Results and discussions

Figure X illustrates the finite element discretization adopted for the numerical analysis of the wall assembly. An unstructured tetrahedral mesh was generated to accurately represent the multilayer building envelope and the geometric discontinuity associated with the wall-to-wall thermal bridge. The mesh was intentionally refined in the vicinity of the junction, where significant temperature gradients and heat flux concentrations were expected, while a coarser discretization was maintained in regions exhibiting relatively uniform thermal fields.

This non-uniform meshing strategy improves the numerical representation of conductive heat transfer without introducing an excessive computational burden. The gradual transition between fine and coarse elements minimizes numerical interpolation errors and avoids abrupt changes in element size that could negatively affect solution convergence. The refinement around the thermal bridge enables a more accurate prediction of local temperature distributions, isothermal contours, and heat flux vectors, which are essential for evaluating the thermal performance of the building envelope.

The mesh conforms well to the interfaces between the different construction layers, allowing the continuity of temperature and heat flux across material boundaries to be properly enforced. Such conformity is particularly important for multilayer assemblies because the thermal conductivity changes significantly between adjacent materials, producing localized variations in heat transfer that require adequate spatial resolution.

The adopted mesh density was selected based on the mesh independence analysis presented in Section 2.3. The comparison between medium and fine discretizations showed variations below 2% for the principal output variables, including surface temperature, heat flux, and linear thermal transmittance. Consequently, the selected mesh provides an appropriate compromise between computational efficiency and numerical accuracy, ensuring stable and reliable FEM solutions while keeping the computational time within practical limits.

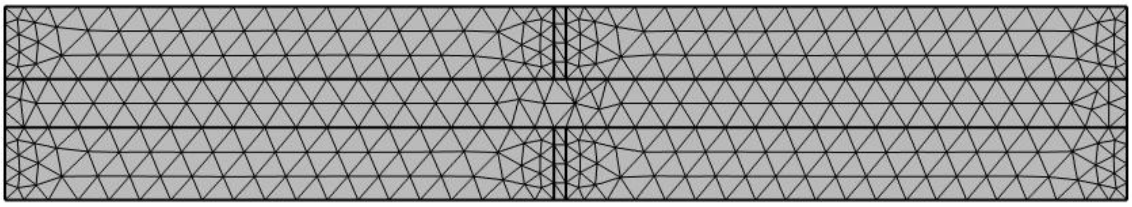

Figure 1. Finite element mesh of the multilayer building envelope with local refinement at the wall-to-wall thermal bridge.

Figure 2 presents the steady-state temperature contours obtained from the three-dimensional FEM simulation using the experimentally measured indoor and outdoor temperatures as boundary conditions. The numerical model reproduces the thermal behavior of the multilayer wall assembly under realistic operating conditions, allowing the identification of temperature gradients and localized heat transfer phenomena associated with the wall-to-wall junction.

The temperature field demonstrates a clear thermal gradient across the building envelope, extending from the conditioned indoor environment toward the colder outdoor side. As expected, the highest temperatures are observed along the interior surfaces of the wall, where the applied boundary condition corresponds to the indoor air temperature. The interior wall surfaces exhibit relatively uniform temperatures, approaching approximately 19–20 °C, indicating that the thermal insulation effectively limits heat losses through the majority of the wall assembly.

Conversely, the exterior surfaces experience considerably lower temperatures, with values ranging approximately between 0 and 5 °C, depending on the exposed location. These lower temperatures are consistent with the outdoor boundary conditions measured during the monitoring campaign and confirm the existence of a significant thermal gradient through the wall thickness.

A noticeable temperature disturbance is observed at the wall-to-wall junction, where the continuity of the insulation is interrupted. This region exhibits compressed isothermal contours, indicating the presence of elevated temperature gradients and intensified conductive heat transfer. Such behavior is characteristic of thermal bridges, where the effective thermal resistance is locally reduced, allowing heat to bypass the surrounding insulated layers.

The thermal bridge creates a localized heat transfer path that modifies both the internal and external surface temperatures. On the indoor side, a slight reduction in surface temperature is observed near the junction compared with adjacent wall regions. Although the reduction appears relatively small, it may become significant under colder outdoor conditions, increasing the risk of surface condensation and reducing thermal comfort for occupants.

Similarly, the external surface surrounding the junction exhibits relatively higher temperatures than neighboring areas. This localized increase results from the larger amount of heat escaping through the thermal bridge and represents one of the principal indicators of increased transmission losses. Such behavior agrees with previous experimental infrared thermography studies, where thermal bridges are typically identified by elevated exterior surface temperatures during winter conditions.

The temperature contours also reveal that the thermal disturbance generated at the junction extends beyond the immediate connection between the two wall segments. Instead of remaining localized at a single point, the heat flow spreads over a finite region around the junction, illustrating the multidimensional nature of conductive heat transfer. This phenomenon cannot be accurately represented using one-dimensional analytical approaches and highlights the importance of three-dimensional FEM simulations for thermal bridge assessment.

The smooth transition of temperature contours throughout the computational domain further demonstrates the numerical stability of the adopted finite element discretization. No abrupt discontinuities or artificial oscillations are observed at material interfaces, indicating that the selected mesh density is sufficient to capture the thermal gradients while maintaining numerical convergence.

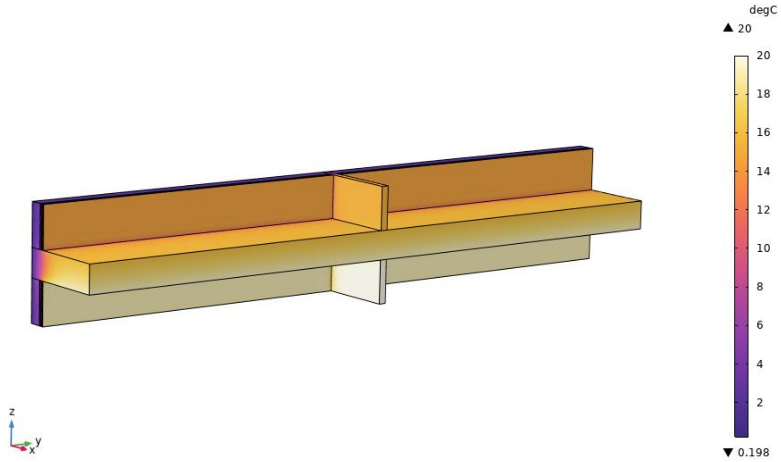

Figure 2. Steady-state temperature distribution obtained from the three-dimensional FEM simulation of the multilayer wall assembly.

Figure 3 presents the steady-state heat flux distribution obtained from the three-dimensional FEM analysis under the experimentally measured boundary conditions. The heat flux contours clearly identify the principal heat transfer paths within the multilayer building envelope and reveal the influence of structural discontinuities on the redistribution of conductive heat flow.

For most regions of the wall assembly, the heat flux remains relatively uniform, with values predominantly ranging between approximately 2 and 4 W/m², indicating that the multilayer wall provides a relatively homogeneous thermal resistance under steady-state conditions. This uniform distribution confirms that, away from structural discontinuities, heat transfer is primarily one-dimensional and perpendicular to the wall surface.

However, significant deviations from this behavior are observed at the structural junctions, where the continuity of the thermal envelope is interrupted. These regions exhibit localized heat flux concentrations, reaching values close to 7 W/m², which are substantially higher than those observed over the surrounding wall surfaces. The increased heat transfer confirms the presence of thermal bridges that locally reduce the effective thermal resistance of the envelope.

The wall-to-wall junction represents one of the most critical thermal bridge locations within the model. A clear concentration of heat flux is observed around the intersection of the two wall segments, where the heat flow changes direction and becomes multidimensional. The convergence of heat flux lines at this location indicates that heat preferentially bypasses portions of the insulated wall through the geometrical discontinuity, increasing the overall transmission losses. This behavior is characteristic of linear thermal bridges and cannot be accurately captured using one-dimensional analytical methods.

Similarly, elevated heat flux values are observed at the wall-to-floor connection. The floor slab provides a continuous conductive path between the interior and exterior portions of the envelope, creating an additional route for heat transfer. The concentration of heat flux along this interface demonstrates that the floor slab contributes significantly to the overall thermal bridge effect, particularly in the vicinity of the external façade.

The wall-to-partition junction also exhibits noticeable heat flux intensification. Although internal partitions are not directly exposed to outdoor conditions, their intersection with the external wall modifies the local heat flow pattern by redistributing thermal energy within the building envelope. This interaction produces localized multidimensional heat transfer, resulting in increased conductive heat flux near the connection region compared with the adjacent wall surfaces.

A similar phenomenon is observed at the partition-to-floor junction, where the intersection between the internal partition and the floor slab creates an additional conductive pathway. While the heat flux concentration at this location is lower than that observed at the exterior wall junctions, the numerical results indicate that the partition influences the thermal field over a relatively large surrounding area. Such effects are generally neglected in simplified building energy calculations but become evident through three-dimensional numerical modelling.

The heat flux contours further demonstrate that thermal bridge effects are not confined to isolated points but extend over finite regions surrounding each structural connection. This spatial redistribution of heat transfer illustrates the multidimensional nature of conduction in complex building assemblies. The gradual variation of heat flux away from the junctions indicates that the thermal disturbance propagates through adjacent materials before returning to a more uniform conductive regime.

Another important observation is the continuity of the heat flux across the interfaces between construction materials. No artificial discontinuities or numerical oscillations are visible in the solution, indicating that the finite element discretization adequately captures the thermal interaction between layers with different thermal conductivities. This confirms both the quality of the computational mesh and the numerical stability of the FEM solution.

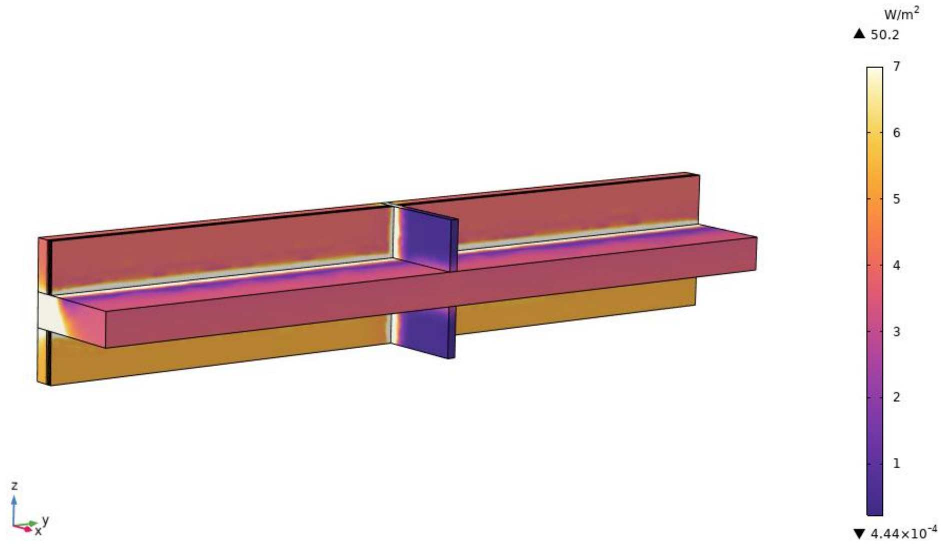

Figure 3. Heat flux distribution obtained from the three-dimensional FEM simulation.

4. Conclusions

This study presented a three-dimensional finite element analysis of thermal bridge behavior in a representative Mediterranean residential building using experimentally measured temperature data as realistic boundary conditions. A digital model of the multilayer building envelope was developed to investigate the influence of structural junctions on temperature distribution and conductive heat transfer within the envelope. The numerical simulations demonstrated that the adopted FEM approach accurately reproduces the thermal behavior of the investigated wall assembly while providing detailed information on local temperature gradients and heat flux distributions that cannot be obtained using simplified one-dimensional analytical methods. The use of in-situ monitored temperatures as boundary conditions enabled the model to realistically represent the operating conditions of the building, improving the reliability of the predicted thermal response. The results revealed that structural discontinuities considerably alter the heat transfer mechanisms within the envelope. Among the investigated configurations, the wall-to-wall and wall-to-floor junctions exhibited the highest heat flux concentrations, confirming their role as the principal thermal bridges responsible for increased transmission heat losses. The wall-to-partition and partition-to-floor connections also generated localized multidimensional heat transfer, although their influence was comparatively less pronounced. These findings demonstrate that even internal structural connections contribute to the redistribution of heat flow and should therefore be considered during the thermal assessment of building envelopes.

The temperature contours further indicated localized reductions in interior surface temperature in the vicinity of thermal bridges, while corresponding increases in exterior surface temperature highlighted the preferred heat transfer paths through the structural junctions. These results emphasize the importance of ensuring insulation continuity and carefully detailing construction joints to reduce energy losses and improve occupant thermal comfort. Overall, the proposed methodology demonstrates the potential of combining IoT-based thermal monitoring with high-resolution three-dimensional FEM simulations for the quantitative evaluation of thermal bridges in existing buildings. The developed approach provides a reliable numerical framework for identifying critical heat-loss regions, supporting retrofit decision-making, and improving the thermal performance of Mediterranean building envelopes. Future work will focus on validating the numerical predictions through infrared thermography and additional in-situ measurements, extending the methodology to transient thermal analyses under varying climatic conditions, and evaluating the effectiveness of different thermal bridge mitigation strategies and advanced insulation solutions for improving building energy efficiency.

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Conflicts of Interest
The authors report no conflicts of interest.

Data Availability Statement
The data supporting the findings of this study, including the experimental temperature measurements, finite element model, and simulation results, are available from the corresponding author upon reasonable request. The data are not publicly available due to ongoing research activities and potential future publications based on the developed methodology.

CRediT Author Statement
Behnam Mobaraki: Conceptualisation, Methodology, Software, Validation, Formal analysis, Investigation, Data curation, Visualization, Writing – original draft, Writing – review & editing, Supervision, Project administration. **Abdollah Mobaraki:** Methodology, Investigation, Data curation, Formal analysis, Writing – review & editing. **Mojdeh Nikoofam:** Investigation, Data curation, Validation, Writing – review & editing. **Laia Mendoza Gordi:** Investigation, Data curation, Validation, Writing – review & editing. **Mohammad Bagher Ahmadi:** Software, Formal analysis, Visualization, Validation, Writing – review & editing. **Frederic Vilà Martí:** Conceptualisation, Methodology, Resources, Supervision, Funding acquisition, Writing – review & editing

Reference
Choi, J. S., Kim, C., Jang, H., & Kim, E. J. (2022). Dynamic thermal bridge evaluation of window-wall joints using a model-based thermography method. *Case Studies in Thermal Engineering*, *35*(February), 102117. https://doi.org/10.1016/j.csite.2022.102117

Curto, D., Franzitta, V., Guercio, A., & Martorana, P. (2022). FEM Analysis: A Review of the Most Common Thermal Bridges and Their Mitigation. *Energies 2022, Vol. 15, Page 2318*, *15*(7), 2318. https://doi.org/10.3390/EN15072318

Hosseinzadehfard, E., & Mobaraki, B. (2025). Corrosion performance and strain behavior of reinforced concrete: Effect of natural pozzolan as partial substitute for microsilica in concrete mixtures. *Structures*, *79*(November 2024), 109397. https://doi.org/10.1016/j.istruc.2025.109397

Mobaraki, A., Nikoofam, M., Mobaraki, Z., Hosseinzadehfard, E., & Mobaraki, B. (2025). Smart Design Policies Implementing an Intelligent Monitoring System to Enhance Energy Efficiency and Support Decarbonization in Sustainable Buildings. *Smart Design Policies*, *2*(1), 19–30.

Mobaraki, B., Castilla Pascual, F. J., Lozano-Galant, F., Lozano-Galant, J. A., & Porras Soriano, R. (2023). In situ U-value measurement of building envelopes through continuous low-cost monitoring. *Case Studies in Thermal Engineering*, *43*(November 2022), 102778. https://doi.org/10.1016/j.csite.2023.102778

Mobaraki, B., Lozano-Galant, F., Soriano, R. P., & Pascual, F. J. C. (2021). Application of low-cost sensors for building monitoring: A systematic literature review. *Buildings*, *11*(8). https://doi.org/10.3390/BUILDINGS11080336

Mobaraki, B., & Vaghefi, M. (2015). Numerical study of the depth and cross-sectional shape of tunnel under surface explosion. *Tunnelling and Underground Space Technology*, *47*, 114–122. https://doi.org/10.1016/j.tust.2015.01.003

Mobaraki, B., & Vaghefi, M. (2024). The Effect of Protective Barriers on the Dynamic Response of Underground Structures. *Buildings*, *14*(12). https://doi.org/10.3390/buildings14123764

Omle, I., Askar, A. H., Kovács, E., & Bolló, B. (2023). Comparison of the Performance of New and Traditional Numerical Methods for Long-Term Simulations of Heat Transfer in Walls with Thermal Bridges. *Energies*, *16*(12). https://doi.org/10.3390/en16124604

Polverino, S., Ahmad Nia, H., Rahbarianyazd, R., & Mobaraki, B. (2025). A Proposed Post-Fire Planning Approach Based on DEMATEL in Vesuvius National Park. *Sustainability (Switzerland)*, *17*(22), 1–35. https://doi.org/10.3390/su172210325

Porras, R., Mobaraki, B., Liu, Z., Muñoz, T., Lozano, F., & Lozano, J. A. (2025). Assessment of Low-Cost Sensors in Early-Age Concrete: Laboratory Testing and Industrial Applications. *Applied Sciences (Switzerland)*, *15*(15), 1–23. https://doi.org/10.3390/app15158701

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