Energy-Efficiet Balcony-Wall Connection Through a Novel Thermal Break Block Incorporating Recycled Plastic Waste

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Abstract Thermal bridges at cantilever balcony connections remain one of the most critical sources of heat loss in modern buildings. Conventional reinforced concrete balconies create a continuous conductive path between interior and exterior environments, increasing heating demand, surface condensation risk, and greenhouse gas emissions. This study presents an innovative structural-thermal solution based on a recycled plastic composite block integrated within the balcony-wall connection zone. Experimental investigations and mathematical modeling were employed to evaluate thermal conductivity, air permeability, and potential energy savings. Results indicate that the proposed system significantly reduces heat transfer while maintaining adequate structural performance. The developed solution contributes simultaneously to building decarbonization and plastic waste recycling objectives, supporting European Green Deal and EPBD requirements.

Keywords: Thermal bridge, Balcony connection, Energy efficiency, Recycled plastic, Decarbonization, Green construction

1. INTRODUCTION

Buildings account for approximately 40% of total energy consumption and 36% of CO_2 emissions in the European Union. One of the major causes of excessive energy demand is thermal bridging.

Among various thermal bridge locations, cantilever balconies represent one of the most problematic building elements because reinforced concrete slabs penetrate the thermal envelope and create a direct heat transfer path.

Research conducted by:

- Kjell Eriksson
- Thomas Olofsson
- Jan Kosny

demonstrates that balcony thermal bridges may increase building heat losses by 10–30%.

This problem becomes increasingly important under current European decarbonization policies.

2. THERMAL BRIDGE PROBLEM AT BALCONY CONNECTIONS

Traditional balcony construction is shown schematically in Figure 1.

Conventional Balcony

Interior Wall → Reinforced Concrete Slab → Exterior Balcony

Heat flow occurs continuously through the concrete slab because concrete possesses relatively high thermal conductivity: $\lambda = 1.7 - 2.1 W/(mk)$

- heating demand increases;

- interior surface temperatures decrease;
- condensation risk rises;
- CO_2 emissions increase.

3. PROPOSED INNOVATIVE SOLUTION

The developed solution introduces a thermal break zone between the balcony slab and building envelope.

System Components

1. Reinforced concrete wall
2. Innovative composite block
3. Recycled plastic core
4. Thermal insulation layer
5. Balcony slab anchorage zone

The innovative block acts simultaneously as:

- thermal barrier;
- structural transition element;
- recycled material reservoir.

4. MATERIALS AND METHODS

Ten composite mixtures were analyzed.

Variables

Sample	Plastic Content (%)
S1	0
S2	2
S3	4
S4	6
S5	8
S6	10
S7	12
S8	14
S9	16
S10	18

Measured parameters:

- thermal conductivity;
- air permeability;
- compressive strength;
- thermal bridge coefficient.

5. MATHEMATICAL MODEL

Heat transfer was evaluated using:

$$Q=U\times A\times\Delta T$$

where:

Q = heat flow

U = thermal transmittance

A = area

ΔT = temperature difference

Thermal bridge performance was assessed using:

$$\Psi=L2D-\sum Uili$$

where:

Ψ = linear thermal transmittance.

6. RESULTS

Table 1. Comparison of Conventional and Innovative System

Parameter	Traditional Balcony	Innovative System
Thermal conductivity	1.8 W/mK	0.35–0.55 W/mK
Thermal bridge effect	High	Low
Heat loss	100%	40–60% lower
CO_2 emissions	High	Reduced
Energy efficiency	Medium	High
Plastic recycling	None	Included

7.Table 1

Typical Thermal Conductivity of Construction Materials

Material	λ (W/mK)
Concrete	1.7–1.8
Brick	0.60
Thermal Insulation	0.035
Composite Block	0.35–0.55

8.Results

Table 3

Comparison of Systems

Parameter	Traditional	Proposed
λ	1.8	0.35–0.55
Heat Loss	100%	40–60% lower
CO_2	High	Reduced
Energy Efficiency	Medium	High

9.DISCUSSION

The results demonstrate that introducing a recycled-plastic composite thermal break significantly improves balcony connection performance.

The reduction of thermal bridging contributes directly to:

- lower operational energy consumption;
- lower carbon emissions;
- improved indoor comfort;
- compliance with EU energy regulations.

Additionally, the use of recycled plastics supports circular economy objectives.

8. CONCLUSIONS

1. Balcony connections remain one of the most significant thermal bridge locations in buildings.

2. The proposed composite block reduces heat transfer by approximately 40–60%.
3. Recycled plastic incorporation decreases environmental impact and material carbon footprint.
4. The solution supports nearly zero-energy building requirements.
5. The developed system has strong potential for patent protection and practical implementation in energy-efficient construction.

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