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PASSIVE INTELLIGENT RADIANT COOLING AND HEATING FOR ZERO ENERGY HOUSE

Summary

This study presents a passive intelligent radiant cooling (PIRC) concept and radiant heating system for nearly zero-energy solar house based on the enthalpy use of city water combined with source-flow ventilation. The proposed system was experimentally evaluated in a residential building to assess its cooling potential under low-energy operation and radiant heating combined to winter garden. According to DIN EN 14240, the PIRC achieved a cooling capacity of 57.7 W/m², while an additional 30 W/m² was obtained from the heat exchanger integrated into the fresh-air inlet. The combined cooling capacity reached approximately 87.7 W/m², demonstrating the feasibility of passive cooling for residential applications with minimal auxiliary energy demand in South Korea. A same passive concept of radiant cooling and heating system is implemented also in Antalya, Türkiye, where is designed to operate independently from the electricity and water grids and planned according to an off-grid concept. The proposed concept provides a practical basis for pilot-scale implementation in climate-responsive passive solar house.

Keywords: *passive intelligent radiant cooling, source-flow ventilation, city water enthalpy, nearly zero-energy building, residential cooling, thermal comfort*

Field of application for the findings: *Residential buildings, nearly zero-energy apartments, passive cooling systems, low-carbon HVAC design*

Addressed audience: *Building energy researchers, HVAC engineers, architects, sustainable building designers, solar building specialists*

1. Introduction

The increasing cooling demand of buildings has intensified the need for low-carbon thermal conditioning strategies that can reduce both operational energy use and peak electricity demand. This challenge is particularly relevant for nearly zero-energy residential buildings, where space cooling must be achieved with minimal fossil energy input while maintaining indoor thermal comfort. Within this context, the present study investigates a passive intelligent radiant cooling (PIRC) concept developed for nearly zero-energy solar house. The proposed PIRC strategy utilizes the enthalpy of city water as a natural cooling source and combines radiant cooling with source-flow ventilation. Unlike conventional vapour-compression systems, the concept seeks to exploit naturally available thermal potential through simple heat exchange and controlled ventilation. This approach is especially relevant in ecological building design, where passive or low-energy solutions are preferred to reduce system complexity and operating cost.

The passive cooling concept is part of a broader building strategy in which passive and active technologies are integrated according to ecological design criteria. In this framework, envelope optimization, ventilation design, and renewable energy harvesting are considered together rather than separately. As a result, the cooling system is not treated as an isolated HVAC component but as a building-integrated element within a nearly zero-energy residential concept.

2. Methodology

The PIRC system was experimentally tested in a residential building environment. The system concept combines a water-based radiant cooling surface with a heat exchanger located at the fresh-air inlet in order to enhance the cooling effect of ventilation air. The essential principle is to use the enthalpy difference between inlet and outlet tap water to remove indoor sensible heat while minimizing additional power consumption. The cooling capacity of the passive radiant component was evaluated according to DIN EN 14240.[1] In parallel, separate heat exchanger experiments were carried out to estimate the cooling contribution achievable through pre-cooled fresh air. The combined performance of the radiant cooling surface and the heat exchanger was then assessed in order to estimate the total passive cooling potential of the proposed system in South Korea. Figure 1 shows the floor pipe plan for the PIRC which utilizes the embedded pipeline of already existing radiant heating system for the purpose of cooling.

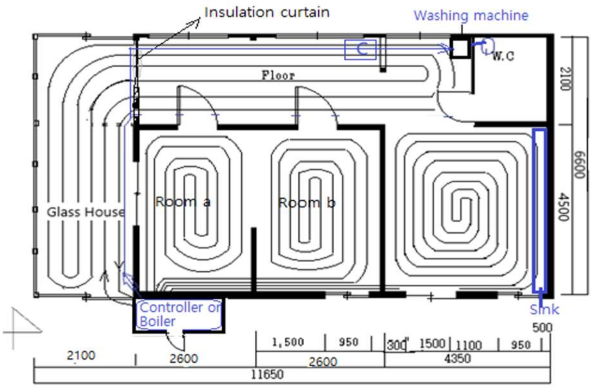

Fig.1: Floor pipe plan for the PIRC

Table 1 shows the experimental results and planned test room of the passive intelligent radiant cooling system.

Tab. 1: Experimental results and planned test room of the passive intelligent radiant cooling system

Parameter	**Value**	**Description**
Cooling capacity of PIRC	57.7 W/m²	Evaluated according to DIN EN 14240
Additional cooling by fresh-air heat exchanger	30.0 W/m²	Contribution from planned fresh-air inlet heat exchanger
Standard test room size	4 × 4 × 3 m	Planned comparative test rooms according to DIN EN 14240

To support future validation, a dedicated standard test facility has also been planned. Two identical test rooms with dimensions of 4,000 × 4,000 × 3,000 mm are being prepared for comparative testing under controlled conditions. This test setup is intended to provide a reproducible basis for further evaluation of passive cooling performance and thermal comfort under real operating scenarios.

A same passive concept of radiant cooling and radiant heating system is implemented also in Antalya, Türkiye, where is designed to operate independently from the electricity and water grids and planned according to an off-grid concept. The architectural layout plan of the pilot implementation where the system integration and testing activities within the scope of the project will be carried out is shown in Figure 2. This Figure is showing two different sections of this house which are considered for cooling and heating systems radiation.

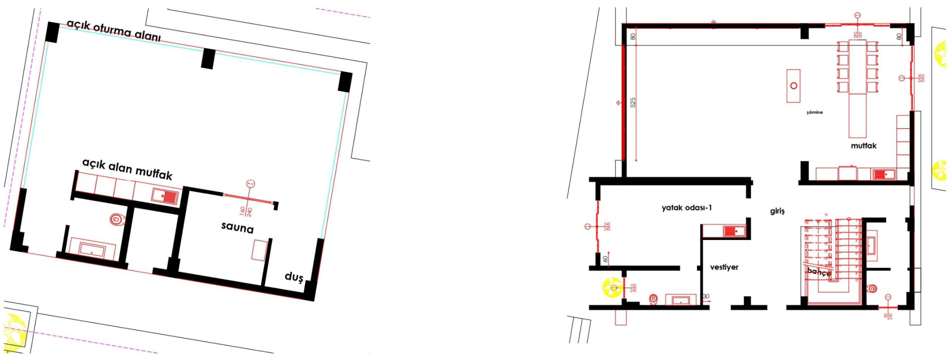

Fig. 2: Architectural layout plan of the pilot implementation building.

The dynamic analysis of the operational energy savings and the recovery potential that the radiant cooling system in Turkiye (New installation) and South Korea (Remodelling) will provide compared to mechanical compressor-based convective HVAC systems will be carried out in the context of LCA analysis.

3. Results and Discussion

The results showed that the passive intelligent radiant cooling system achieved a cooling capacity of 57.7 W/m². When the heat exchanger planned for the fresh-air inlet was taken into account, an additional 30 W/m² was obtained, resulting in a total cooling capacity of approximately 87.7 W/m². This total value indicates that a substantial portion of residential cooling demand can be covered through passive thermal exchange without relying on conventional refrigeration equipment. The significance of the result lies not only in the magnitude of the cooling capacity, but also in the operational principle of the system. By using the thermal potential of city water and integrating it with source-flow ventilation, the proposed concept reduces the dependence on mechanically intensive cooling systems. This makes the system particularly suitable for ecological and cost-sensitive residential applications where energy-efficient cooling is required without large additional infrastructure.

The system also demonstrates the importance of integrating radiant cooling and ventilation rather than treating them as separate subsystems. The radiant cooling surface addresses sensible load reduction, while the fresh-air heat exchanger improves the thermal condition of supply air. Together, these measures improve indoor comfort and extend the practical applicability of passive cooling in residential buildings.

From a building integration perspective, the proposed system can be combined with other nearly zero-energy technologies, including photovoltaic electricity generation and heat pump backup under extreme conditions. In this way, passive cooling can serve as the primary mode during favorable operation, while renewable electricity supports active conditioning only when necessary. Such hybrid operation is consistent with the broader objective of minimizing operational carbon emissions. Additionally, life cycle simulations indicate that integrating circular economy strategies can reduce the project's total carbon footprint by over 50%, aligning with international NZEB sustainability targets. The LCA analysis will be the meaningful results for the PIRC.

4. Conclusions

This study demonstrated the feasibility of a passive intelligent radiant cooling concept based on city-water enthalpy and source-flow ventilation for passive solar house with wintergarden. The experimentally verified cooling capacity of 57.7 W/m², together with an additional 30 W/m² from the fresh-air heat exchanger, resulted in a total passive cooling capacity of approximately 87.7 W/m².

The findings confirm that passive cooling can provide a meaningful share of residential cooling demand while requiring only minimal auxiliary energy. The system therefore represents a technically credible and ecologically attractive strategy for low-carbon residential cooling. Future work will focus on validation according to standard test condition, long-term monitoring, and climatic adaptation in full-scale demonstration buildings.

5.Acknowledgments

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6. Reference

1.DIN EN 14240, 2004. Ventilation for buildings - Chilled ceilings - Testing and rating.

2.Hansen,R.N. et al, 2023. "A systematic review of consequential LCA on buildings: the perspectives and challenges of applications and inventory modelling," International Journal of Life Cycle Assessment.