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A Review of Thermally Activated Building Systems (Tabs): A Sustainable Solution for Energy-Efficient Building Design

Shubham Pariskar, Research Scholar, Sunrise University, Alwar, Rajasthan
Dr. Mahender Kumar, Associate Professor, Sunrise University, Alwar, Rajasthan

Abstract

One of the options for increasing thermal comfort in buildings is thermally activated building systems (TABS). They are placed in different parts of the house to improve the air in the house. In this study, the latest technology of TABS is examined and analyzed to determine its potential for improving thermal comfort and saving energy. In addition, this study also fills the gaps in the literature and enables researchers to conduct future studies on TABS. Factors and mass flow were analyzed. paper classify and analyze in four parts considering their implementation in roofs, walls, floors, and the whole envelope. The study found that indoor temperatures could be reduced by up to 12°C when TABS was used on the roof, walls and floor. Limitations of TABS include its complexity and cost of use compared to air conditioning. However, TABS can provide energy savings of up to 60%.

Keywords: thermally activated building systems; thermal comfort; thermal mass; energy savings; heat exchanger pipes.

1) INTRODUCTION

Thermally Activated Building Systems (TABS) are a new way to improve the energy of a building by using building materials to control the temperature in the building. These systems have pipes in the concrete floor, ceiling or wall that control waters to heat or cool the building. TABS uses materials made from building materials with great thermal properties, such as concrete, to absorb, Store and release heat over time. TABS provides consistent comfort without changing heating and cooling by controlling the interior temperature integrating TABS with renewable energy sources such as solar or geothermal energy further increases its environmental benefits by reducing reliance on intermittent power supply. It is estimated that the amount of energy consumed by the residential and construction sector in 2018 was 36%, of which 39% ofthe energy was related to CO2 emissions worldwide [1].

TABS systems also help reduce a building's carbon footprint and support global sustainability goals. The technology can be integrated with a smart home to manage more energy and increase efficiency. TABS provide consistent comfort without changing heating and cooling by controlling the interior temperature. The technology can be integrated with a smart home to manage more energy and increase efficiency. TABS in their long-term benefits in terms of energy savings and user comfort make them useful in the context of building a sustainable building [2].Using water as the working fluid in TABS increases energy savings because water can transport energy 3500 times more effectively than air. Among the advantages of using TABS over HVAC systems are: high indoor air quality, greater energy efficiency and smaller size, and low maintenance costs[3]. TABS will play a significant role in reducing energy consumption in buildings worldwide, contributing to the fight against climate change.

2)TABS Implantedin Building Roofs

2.1Potential for improved thermal comfort when TABS is installed on the roof.

The roof is generally the building material most exposed to heat and cold, and it receives solar energy for longer periods of time than other materials. indoor thermal comfort. This section focuses on research into the integration of TABS into the roof. This article describes technological developments in thermal comfort, its combination with other technologies and the resulting energy savings. TABS has the ability to increase thermal comfort when installed on the roof. The heat in a building depends on different factors such as relative humidity of the air, air temperature, and air velocity [4,5]. Many studies have been conducted to determine the effect of roofs with TABS on the indoor air of buildings and this can be considered as a way to measure the thermal comfort improvement from TABS. One of the first studies was by Gwerder et al. [6] who proposed the TABS control algorithm to ensure comfort. The scheme combines the transfer of TABS heating and cooling modes to meet the thermal comfort. The algorithm was tested in a simulation example. Hourly temperature

measurements show that TABS maintains indoor air temperature between 21 and 27°C throughout the year. Wit and Wisse reported an alternative control method for TABS in which operation (heating or cooling) is determined by the average indoor air temperature [7].
They analyzed the thermal behavior of various types of hydraulic TABS integrated on the roofs of two office buildings. After many tests, the results showed that TABS was able to control the comfort of the two houses, since during the test the satisfaction rate of most of the air conditioners in the house dropped to 80% to 90%. In another study on rooftops that included TABS, Rey Martinezet al. [8] The indoor air quality and thermal comfort of the building were analyzed. The building has four floors, air conditioning by means of TABS and chillers. The authors found that the operating temperature was maintained at 23 to 25 °C during the stay and the carbon dioxide level was maintained at 850 ppm. The simulation study of buildings with TABS roofs was described by Chung et al. [9].
Energy Plus simulation software was used to apply different control strategies in all areas of the study materials. The authors divided the experiment into three runs by changing the temperature of the indoor and outdoor heating and cooling areas from 19 to 25 °C. Zhong et al. concluded that thermal comfort was increased by 5% by dividing the building plan into zones with different control strategies according to the needs of each building. Experimental studies reported by Dharmasastha et al. [10] analyzed the thermal behavior of a TABS hybrid system combined with glass fiber reinforced gypsum roof (TAGFRG). They constructed a test room with 0.01-meter diameter copper pipes on the roof in the hot and humid area of Chennai, India. The authors found that TABS reduced the roof surface temperature by 5.1 °C and the indoor air temperature in the laboratory by 6.7 °C. The thermal behavior of a closed-loop pulsating heat pipe (CLPHP) roof cooling system was investigated and compared with a bare metal roof system design. The authors recommend the Rooftop CLPHP as a cooling system for hot weather. The system consists of a closed system of copper pipes placed on two aluminum panels under the roof sheet and insulated from the bottom. Methanol is used as the working fluid in the copper cycle. They use two halogen lamps to simulate solar radiation. Saw et al. found that the CLPHP-cooled roof reduced the laboratory's indoor temperature from 34°C to 29.6°C compared to the bare roof.
2.2TABS can reduce energy consumption when installed on the roof.
Two case studies found a reduction in energy consumption of air-conditioned buildings due to the use of TABS on the roof. In the first study, Lehmann et al. [11] examined the scope of operation and application of TABS by simulating a working environment in TRNSYS. The authors analyze thermal comfort, maximum allowable heating of the room and cooling of the building. The second study is the simulation study done by Zhong et al. [9] also estimated the effect of roof-mounted TABS on the thermal load of the building structure. They found that, compared to reference materials, heating load was reduced by 10%, cooling load by 36% and total energy consumption by 13% with TABS.
3.**TABS Implanted in Building walls.**
3.1 Potential for improved thermal comfort when TABS areinstalled on the walls.
Building wall is another type of building envelope component that can exchange energy with the external space due to its large area. Many researches have been done on TABS in walls. TABS embedded in walls is a solution that improves their thermal performance by increasing or decreasing the heat and saving energy. The purpose of this section is to introduce simulation methods to predict TABS behavior, the most suitable one, and other techniques to improve the design and structure of TABS.
Several studies aim to model building systems and use TABS (Thermal Active Building Systems) to assess the thermal performance of walls. The authors employed different methods for system analysis, including Resistance-Capacitance (RC), Number of Transmission Units (NTU), and Finite Difference (FD). Key water parameters such as inlet temperature, velocity, and mass flow rate were also examined. Some of these studies have been validated with experimental data, such as the research conducted by Todorović et al. [12]
Other studies have examined the influence of pipe layout, spacing, and distance on indoor temperatures. Jiang et al. [13] investigated the impact of preparation speed and work type on

water temperature variation. In their numerical study, they compared two TABS configurations: a connected wall with channels (SPW) and a connected wall with embedded channels (PPW). The authors found that the water temperature has a significant effect on both the water temperature itself and the indoor temperature, particularly in tropical climates. The authors concluded that when TABS is used for heating, energy savings of up to 75% can be achieved at a temperature of 18°C. They also noted that while TABS is typically used for heating purposes, any type of renewable energy can be utilized to power the system.

4. **TABS Implanted in Floor**

This segment focuses on TABS integrated within the floor, their configurations, and the materials used to improve the thermal comfort of buildings. A few researchers have chosen to analyze floor TABS by simulating their behavior to enhance thermal comfort. Joe and Karava [14] developed a model predictive control (MPC) system to optimize its behavior, reduce energy consumption and costs, and increase thermal comfort. The authors compared simulated and experimental data from three buildings in both heating and cooling modes: (1) with a hydronic radiant floor system, (2) with a wall diffuser, and (3) with a ceiling diffuser. They found significant energy and cost reductions compared to a conventional HVAC system. The cost savings were approximately 34%, and the energy savings were 16%. Meanwhile, the building with the radiant floor system achieved energy savings of 50% and 29% compared to buildings 2 and 3. A few researchers have analyzed the behavior of TABS using different construction materials in the floor. To examine its thermal behavior and heat storage capacity, Ma et al. [15] proposed a radiant floor with embedded channels. The authors analyzed the thermal behavior of the radiant concrete slab both experimentally and with a simplified model. They compared two concrete slabs with aluminum-plastic (XPAP) embedded channels, one with aluminum fins attached to the underside of the pipes and the other with embedded tubes without fins. Water was circulated through the channels at three different temperatures: 25.0°C, 29.8°C, and 34.6°C.

The authors found that the radiant floor with aluminum fins reduced the temperature through the concrete slab and improved heat storage, with the performance increasing exponentially as the fin height increased. The authors concluded that the height and material of the fins integrated into the tubes have a significant impact on the energy storage rate.

Floor TABS have also been integrated with other systems to improve system efficiency and thermal performance. Stop et al. [16] conducted a study to assess the thermal comfort and energy consumption of a TABS combined with a radiant floor heating system (RFHS) and a pack air conditioning (PAC) system. The authors found that combining TABS with other systems improved thermal comfort. However, the TABS-PAC and TABS in cooling mode configurations maintained the indoor comfort conditions.

5. TABS Integrated in Various Building Components

This section presents the TABS studied for reducing or increasing the indoor temperature of buildings when introduced in more than one building component. Researchers worldwide have analyzed various parameters and scenarios involving TABS, and several have evaluated the use of TABS across the entire building envelope. TABS have been studied to decrease or increase the indoor temperature of buildings. These systems can be integrated into one or multiple building envelope components and can be combined with other technologies.

Khan et al. [17] utilized a TABS integrated within the roof and floor, operating in cooling mode. The authors performed simulations using MATLAB and Energy Plus to assess the thermal behavior and energy-saving potential of TABS. The models were calibrated and validated with experimental data. The authors proposed two scenarios: one with a conventional air-cooling system and one with the proposed TABS. They found that the TABS provided up to 30% energy savings compared to the conventional system.

6. Results and Discussion

The objective of this study was to review the state of the art of TABS. In this study, the thermal behavior of TABS in roofs, walls, and floors was examined. TABS can be implemented in both a building component and the entire envelope, helping to maximize its efficiency

In the literature review, it was found that TABS can be referred to by different names depending on their location in the envelope and their mode of operation, such as thermally activated building constructions, radiant cooling/heating systems, and active building storage systems, among others. The development of this study helped us identify the main variables that were analyzed by the authors.

Most of the detailed studies analyzed the behavior of indoor ambient temperature in order to achieve thermal comfort. Other aspects examined by the authors included the impact of changing the properties of the fluid on indoor ambient temperature, the energy-saving potential, and the capacity of the cooling/heating stack.

With respect to the improvements in thermal comfort provided by TABS when installed in building roofs, the results are reported in terms of reductions in indoor air temperature (6.7 °C) [10], the range within which the indoor air temperature stays (21–28 °C) [6], and the percentage of time the indoor temperature is within the comfort zone (80–90%) [7]. On the other hand, the energy savings provided by TABS when implanted in building roofs were reported in several studies [11].

It was shown that TABS can provide energy savings ranging from 13% to 50%. Other studies suggest that when TABS are integrated into more than one building envelope component, they make a significant contribution to improving thermal comfort. The results are reported in terms of reductions in indoor air temperature or the duration for which the indoor air temperature remains within the desired range.

When the roof and floor were equipped with implanted TABS and used for cooling, it was shown that the indoor air temperature was reduced by between 4.4 and 9.5 °C. From the review of the available literature, it is possible to identify options that can contribute to thermal comfort in buildings. TABS is one of these options that offers many benefits, although it also has some limitations. Among the benefits reported by the authors is the integration of TABS with systems that use renewable energy in the heating mode, as well as the distribution of the working fluid of TABS to meet the needs of the building's occupants.

7. Conclusions

This study provides a review of the current state of TABS, examining its various configurations and its application in different building components (roof, wall, and floor) or across the entire envelope. Additionally, the integration of TABS with other systems was explored. Key findings from the literature regarding the thermal performance and critical parameters of these systems were also discussed. TABS are emerging as a promising area of research for those studying strategies to enhance the indoor environment of buildings.It can be said that TABS are systems with both limitations and opportunities. The primary limitations are the installation and implementation costs. However, any new development that alters the conventional approach to construction has implications that are reflected in the costs of installation, operation, and maintenance.

References

1. IEA. Global Status Report for Buildings and Construction: Towards a Zero-Emissions, Efficient and Resilient Buildings and Construction Sector; IEA: Paris, France, 2019.
2. IPCC. Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change; IPCC: Geneva, Switzerland, 2014; 151p.
3. Resources, E.D. Radiant Cooling, Energy Design Resources: Building Envelope Design; Financial Times Energy, Inc.: Boulder, CO, USA, 2003.
4. Dong, W.; Chen, Y.; Bao, Y.; Fang, A. A validation of dynamic hygrothermal model with coupled heat and moisture transfer in porous building materials and envelopes. J. Build. Eng. 2020, 32, 101484.
5. Wei, M.; Wang, B.; Liu, S. Numerical Simulation of Heat and Moisture Transfer of Wall with Insulation. J. Phys. Conf. Ser. 2019, 1300, 012029.
6. Gwerder, M.; Lehmann, B.; Toddle, J.; Dorer, V.; Renggli, F. Control of thermally-activated building systems (TABS). Appl. Energy 2008, 85, 565–581.

7. De Wit, A.; Wisse, C. Hydronic circuit topologies for thermally activated building systems-design questions and case study. *Energy Build*. 2012, 52, 56–67.
8. Rey Martínez, F.J.; Chicote, M.A.; Peñalver, A.V.; Gonzalez, A.T.; Gómez, E.V. Indoor air quality and thermal comfort evaluation in a Spanish modern low-energy office with thermally activated building systems. Sci. Technol. Built Environ. 2015, 21, 1091–1099.
9. Chung, W.J.; Park, S.H.; Yeo, M.S.; Kim, K.W. Control of thermally activated building system considering zone load characteristics. Sustainability 2017, 9, 586.
10. Dharmasastha, K.; Samuel, D.L.; Nagendra, S.S.; Maiya, M. Experimental investigation of thermally activated glass fiber reinforced gypsum roof. Energy Build. 2020, 228, 110424.
11. Lehmann, B.; Dorer, V.; Koschenz, M. Application range of thermally activated building systems tabs. Energy Build. 2007, 39, 593–598.
12. Todorovi´c, R.I.; Banjac, M.J.; Vasiljevi´c, B.M. Analytical and experimental determination of the temperature field on the surface of wall heating panels. Therm. Sci. 2015, 19, 497–507.
13. Jiang, S.; Li, X.; Lyu, W.; Wang, B.; Shi, W. Numerical investigation of the energy efficiency of a serial pipe-embedded external wall system considering water temperature changes in the pipeline. J. Build. Eng. 2020, 31, 101435.
14. Joe, J.; Karava, P. A model predictive control strategy to optimize the performance of radiant floor heating and cooling systems in office buildings. Appl. Energy 2019, 245, 65–77.
15. Ma, J.; Yang, Y.; Zheng, X.; Dai, B.; Zhu, D.; Liu, Q. Impact on heat storage performance of concrete radiant floor with finned water supply pipes. J. Build. Eng. 2021, 44, 103351.
16. Park, S.H.; Chung, W.J.; Yeo, M.S.; Kim, K.W. Evaluation of the thermal performance of a Thermally Activated Building System (TABS) according to the thermal load in a residential building. Energy Build. 2014, 73, 69–82.
17. Khan, Y.; Khare, V.R.; Mathur, J.; Bhandari, M. Performance evaluation of radiant cooling system integrated with air system under different operational strategies. Energy Build. 2015, 97, 118–128.
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