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Development of Lightweight Energy Storage Cladding Panels for Building Applications

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ABSTRACT

Buildings contribute significantly to global energy consumption and energy-related CO_2 emissions, primarily due to the use of mechanical air-conditioning systems. The building envelope directly impacts the heating and cooling requirements, becoming the focal point for many buildings' energy-efficiency studies. Two key properties are commonly addressed to improve the building envelope thermal performance, namely thermal resistance, i.e., reducing heat gains/losses via thermal insulations, and thermal mass, i.e., the ability of heavy structures to delay heat and reduce indoor temperature fluctuations. In modern lightweight structures, thermal mass can be achieved by incorporating thermal storage materials like phase change materials (PCMs). This study combines both properties in a single application by utilizing foam concrete (FC), with a low thermal conductivity of 0.40W/mK, as a matrix to integrate microencapsulated PCM (MPCM), with a transition temperature and latent heat of 35℃ and 180kJ/kg, respectively, to develop innovative lightweight thermal storage panels (FC_{PCM}) for building cladding. The developed FC_{PCM} composite had a density of 910kg/m³, compressive strength of 6.2MPa, and thermal conductivity of 0.23W/mK, which were lower by 49.7%, 57.2%, and 82.7%, respectively, compared to the conventional cement render. Besides, the FC_{PCM} retained the same transition temperature as the MPCM, while the latent heat was 38.56 kJ/kg, corresponding to the MPCM proportion in the FC_{PCM} composite. Furthermore, the FC_{PCM} composite was then used to develop the cladding panels, which were tested in a controlled environment and achieved up to 33.3% reduction in heat flux compared to panels made from cement render. The FC_{PCM} panels were also experimentally investigated as external cladding on a cement brick wall. The experimental assessment was performed under the actual weather, and the results showed significant improvement in the thermal performance of the wall finished with the FC_{PCM} cladding panels compared to a reference wall finished with cement render. The FC_{PCM} panels effectively managed to reduce heat gain, resulting in a lower wall's internal surface temperature by up to 6.75℃, 6.50℃, 5.00℃, and 2.45℃ for the west, south, east, and north-oriented walls, respectively, keeping the indoor temperature lower by 5.45℃, 5.5℃, 4.35℃, and 2.45℃, respectively. Moreover, installing the cladding panels mechanically on the wall with a ventilated cavity of 2 cm between the cladding panels and the wall further decreased the wall's internal surface temperature by 2.76℃ compared to the direct installation method.