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Optimization of a Building Wall Using a Bio-Sandwich Panel Composed of OSB and Bio-Based PCM

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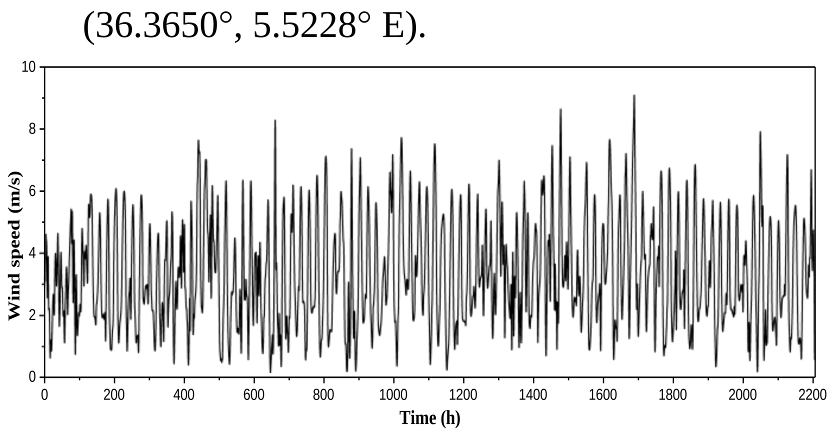
INTRODUCTION & AIM

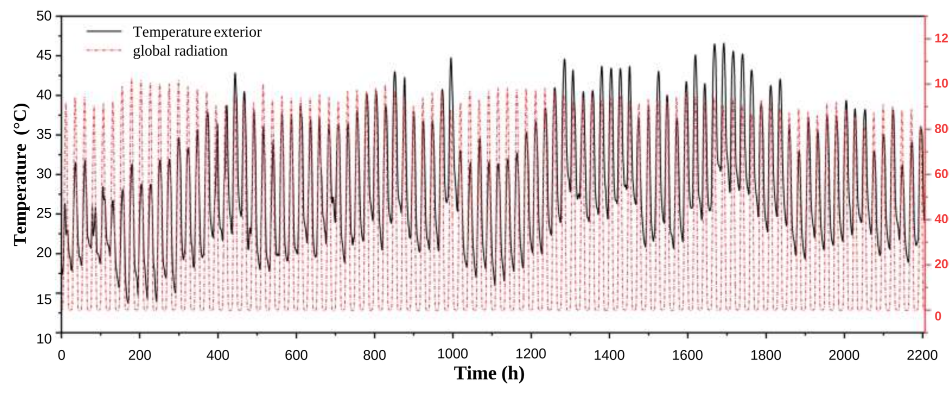
Improving the thermal performance of building envelopes while reducing construction costs is a key challenge in sustainable building design. Phase change materials (PCMs) offer an effective solution for thermal energy storage due to their ability to absorb and release latent heat during phase transitions. However, conventional PCM integrations often increase overall thickness, which reduces available indoor space or raises material costs. To address this limitation, this study proposes an innovative wall configuration incorporating a 5 cm bio-sandwich panel composed of oriented strand board (OSB) and a bio-based PCM. Inspired by previous structural designs, the primary objective of this research is to enhance indoor thermal comfort while maintaining a reduced wall thickness, utilizing eco-friendly, low-cost, and renewable materials to optimize both thermal and economic performance.

METHOD

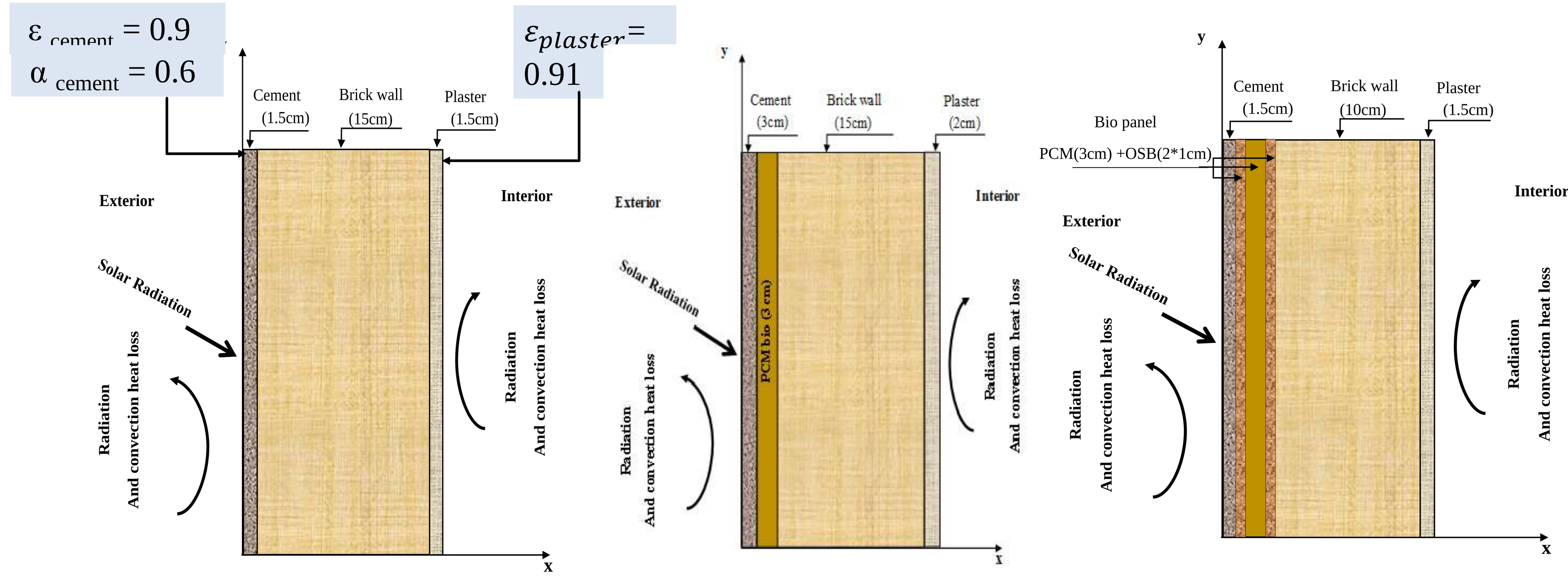
1. Configurations Under Investigation

- **Dimensional Constraint:** Maintenance of a uniform and constant total structural wall thickness fixed at 18 cm across all cases.
- **Reference Assembly (Case 1):** Exterior layer of 1.5 cm cement mortar + structural core of 15 cm standard hollow clay brick + interior layer of 1.5 cm gypsum plaster.
- **Innovative Assembly (Case 2):** Exterior layer of 1.5 cm cement mortar 5 cm multi-layer bio-sandwich panel + 10 cm reduced brick core + 1.5 cm interior plaster.
- **Bio-Sandwich Sequencing:** Internal layer breakdown consisting of a 1 cm exterior OSB skin + 3 cm bio-based PCM core + 1 cm interior OSB skin.
- **Climatic Forcing Data:** Application of real meteorological summer datasets for the city of Constantine, Algeria (36.3650°, 5.5228° E).





Temporal variations in outdoor temperature, total radiation, and wind during the summer in Constantine



On exterior surface:

$$-k_{cement}\frac{\partial T}{\partial x} = h_e(T_e - T_{cement}) + \varepsilon_{cement}\sigma\left(T_e{}^4 - T_{cement}{}^4\right) + \alpha_{cement}I(t)$$

On interior surface:

$$-k_{plaster}\frac{\partial T}{\partial x} = h_i(T_i - T_{plaster}) + \varepsilon_{plaster}\sigma\left(T_i{}^4 - T_{plaster}{}^4\right)$$

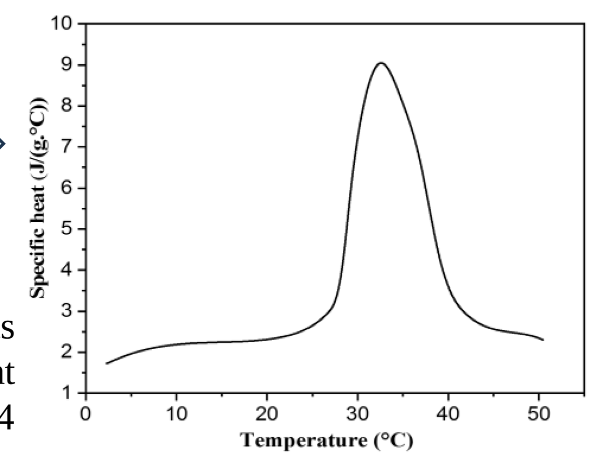
Comparative wall configurations: reference wall according to Z.X. LI et al (20 cm without PCM, 23 cm with PCM) and innovative bio-sandwich wall (18 cm with OSB and bio-based PCM)

2. PCM Used and Developed

The new bio-based PCM developed

Differential Scanning Calorimetry (DSC) Analysis

DSC heat capacity curves for bio-based PCM at a scan speed of 2 (°C/min).



The results show that the PCM melts between 27 °C and 38 °C, with a latent heat of fusion of approximately 64 kJ/kg.

3. Mathematical model

❖ **Continuity Equation :**

$$\frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} = 0$$

❖ **Equation of momentum in PCM:**

$$\rho\left(\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} + v\frac{\partial u}{\partial y}\right) = -\frac{\partial P}{\partial x} + \mu\left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2}\right) + A(T)\times u$$

$$\rho\left(\frac{\partial v}{\partial t} + u\frac{\partial v}{\partial x} + v\frac{\partial v}{\partial y}\right) -= -\frac{\partial P}{\partial y} + \mu\left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2}\right) + A(T)\times v + F_b$$

The correlation-based thermal capacity model based on experimental data:

$$Cp_{eq} = \begin{cases} Cp_s(T) = 1.4327 + 0.1643T - 1.16\times10^{-2}\,T^2 + 2.8\times10^{-4}\,T^3 \\ Cp_{in}(T) = -146.966 + 9.25078T - 0.13690T^2 \\ Cp_l(T) = 40.017 - 1.908T + 3.198\times10^{-2}T^2 - 1.78\times10^{-4}\,T^3 \end{cases}$$

❖ **Energy equation:**

$$\begin{cases} \rho Cp_{eq}\left(\frac{\partial T}{\partial t} + u\frac{\partial T}{\partial x} + v\frac{\partial T}{\partial y}\right) = k\left(\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2}\right) & \text{dans le MCP} \\ \rho Cp\frac{\partial T}{\partial t} + \nabla.(-k\nabla T) = 0 & \text{dans les matériaux de construction} \end{cases}$$

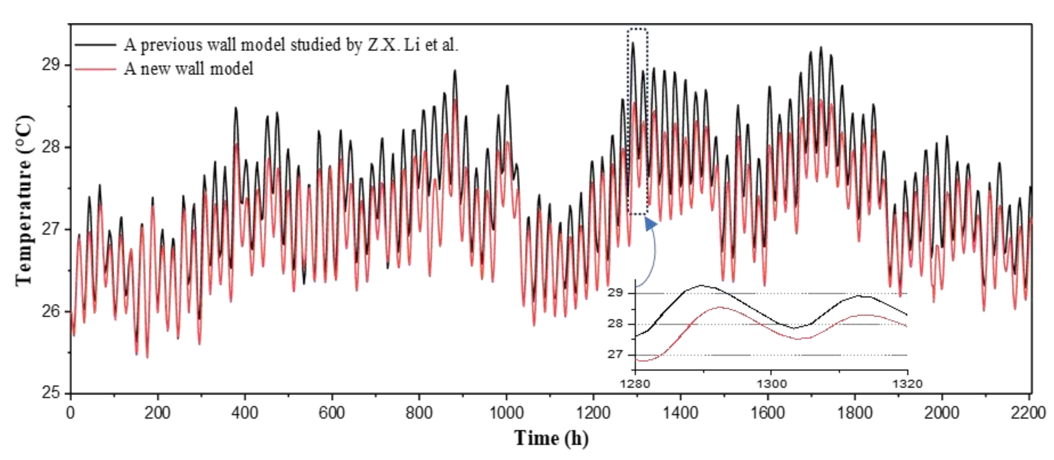
The density of the MCP: $\rho(T) = \rho_s + (\rho_l - \rho_s)\times B(T)$

The function B(T) exhibits a linear behavior in the phase transition region:

$$B(T) = \begin{cases} 0 & T < (T_{pic} - \Delta T) \\ \frac{(T - T_{pic} + \Delta T)}{2\,\Delta T} & T_{pic} - \Delta T \le T \le T_{pic} + \Delta T \\ 1 & T > T_{pic} + \Delta T \end{cases}$$

RESULTS & DISCUSSION

1. Wall Comparison & Cost-Efficiency



A comparison of temperature variation at the inner surface of two wall models.

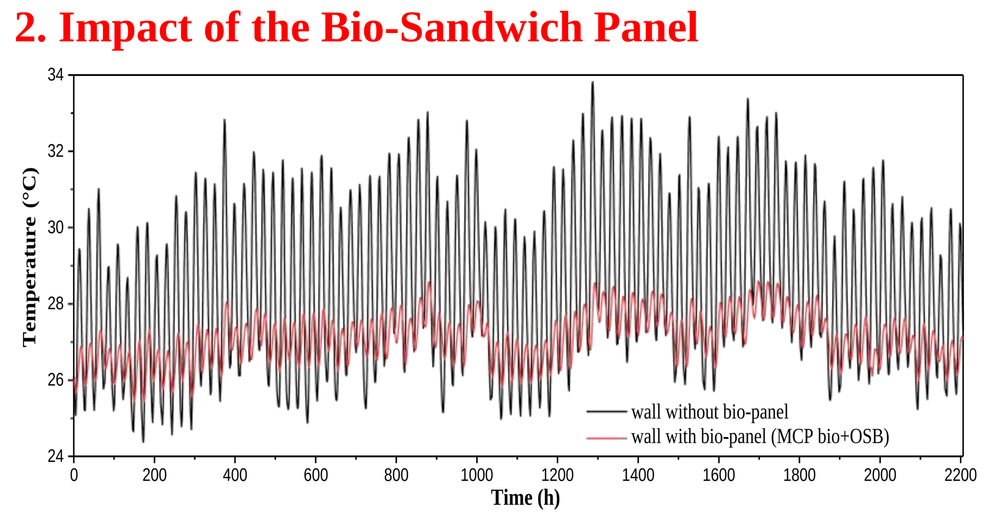
This study introduces an innovative 18 cm wall design that outperforms the traditional 23 cm reference model in both spatial efficiency and material cost.

•**Thickness Reduction**: New model is only 18 cm thick, saving 5 cm of indoor space compared to the 23 cm Li et al. model.

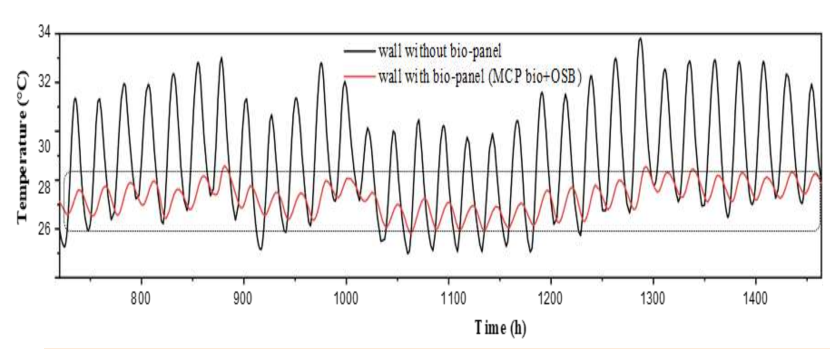
•**Economic Advantage**: Replacing traditional layers (brick, cement, plaster) with low-cost OSB panels (€6/m² for 1 cm) significantly lowers construction costs.

•**Thermal Performance**: Inner surface temperature peaks are reduced by 1°C compared to the Li et al. model, shifting closer to the comfort zone.

2. Impact of the Bio-Sandwich Panel



This figure shows the variation in temperature at inner surface of reference wall and wall with bio-sandwich panel.



A zoom shows the impact of integrating a bio-sandwich panel on the significant reduction in temperature amplitudes inside the wall.

The integration of the bio-sandwich panel (OSB + bio-based PCM) drastically reduces summer temperature fluctuations to ensure optimal indoor thermal comfort.

•**Temperature Stabilization**: Inner surface fluctuations in summer are narrowed to a highly stable 26–28°C range.

•**Amplitude Reduction**: Maximum temperature amplitude drops from 7.2°C (reference wall) to just 1.2°C with the bio-sandwich panel.

•**Smart Heat Storage**: Combines sensible heat storage (OSB and PCM states) with high latent heat storage during PCM phase change.

•**Sustainability**: Uses eco-friendly, renewable, and easily available materials ideal for sustainable construction.

CONCLUSIONS

In conclusion:

This study validates an innovative, sustainable, and highly efficient 18 cm wall design integrating a bio-sandwich panel (OSB + bio-based PCM). The solution reduces construction costs, minimizes wall thickness to 18 cm—saving 5 cm compared to previous models—and achieves exceptional thermal stability by reducing internal surface temperature amplitude from 7.2°C to 1.2°C, ensuring optimal comfort within 26°C-28°C.

FUTURE WORK

•Build a physical prototype wall in Constantine to validate the 1.2°C temperature amplitude under real summer conditions.

•Quantify the carbon footprint reduction achieved by replacing brick and cement with OSB and bio-based PCM.

•Extend the application of the bio-based PCM to optimize the thermal management of hydrogen storage systems.