

## Investigation of Incorporating Polyethylene Glycol 600 (PEG600) into Sustainable Concrete to Evaluate Its Impact on Mechanical Strength and Thermal Behaviour

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### Abstract

This study investigates the effects of incorporating Phase Change Material (PCM), specifically Polyethylene Glycol 600 (PEG600), into sustainable concrete to evaluate its impact on mechanical strength and thermal behavior. The balance between mechanical performance and thermal benefits depends on the PCM dosage, with lower percentages (up to 4%) providing an optimal trade-off. Durability tests suggest that PEG600-modified concrete maintains adequate resistance to environmental factors, although microstructural analysis highlights the need for improved bonding techniques to minimize porosity.

**Keywords:** Sustainable concrete, phase change materials, PEG600, Guar gum, Durability

### 1. Introduction

Traditional concrete production and use have significant environmental impacts, including high carbon dioxide emissions and energy consumption [1-3]. In recent years, there has been growing interest in developing sustainable concrete formulations that reduce environmental footprint while maintaining or improving performance. Polyethylene Glycol (PEG600) is a widely studied organic PCM due to its favorable melting point, thermal stability, and compatibility with cementitious materials. Incorporating PEG600 into concrete has the potential to improve the thermal performance of the material, making it suitable for energy-efficient buildings [4]. This study aims to explore the strength and behavior of sustainable concrete containing PEG600, focusing on how different PCM contents affect compressive strength, thermal performance, and overall material behavior. The findings will contribute to understanding the balance between mechanical integrity and thermal benefits, supporting the development of advanced sustainable concrete for modern construction needs [5]. With increasing global concerns about climate change and energy consumption, the construction industry faces pressure to adopt more sustainable and energy-efficient materials [6-7]. However, the addition of PCMs can potentially affect the mechanical strength and durability of concrete, which are critical for structural safety and longevity. Understanding the trade-offs between enhanced thermal performance and mechanical behavior is essential for practical applications. Various combinations of admixtures and phase change materials to develop new cement-based composite phase change materials for application in insulated wall panels and intelligent buildings. Such as silica fume/decanoic acid-stearic acid, blast-furnace slag/decanoic acid, fly ash/lauric acid-myristate, etc [8-9]. This study is motivated by the need to develop sustainable concrete composites that integrate PEG600 to achieve both energy efficiency and acceptable structural performance, thereby contributing to environmentally responsible construction practices and advancing the use of innovative materials in the industry. Research on PCM-incorporated concrete shows mixed impacts on mechanical properties. [10] found that direct addition of PCMs can reduce compressive strength due to weak bonding and increased porosity, while encapsulation methods can mitigate strength loss. Thermal performance benefits of PCM concrete have been documented in several studies. For instance, [11] highlighted significant temperature damping effects in PCM-enhanced concrete panels, leading to lower peak temperatures and improved energy efficiency. The phase change process helps maintain thermal comfort and reduces HVAC loads. Several researchers have explored the optimal dosage of PEG600 in concrete mixes to balance strength and thermal benefits [12-13]. It observed that PCM content up to 5% by weight can improve thermal behavior without severely compromising strength, whereas higher amounts lead to substantial strength reduction. Overall, the literature indicates that PEG600-based PCM has great potential for enhancing the thermal performance of sustainable concrete but requires careful mix design to maintain mechanical strength. This study aims to build on these findings by systematically evaluating the strength and behavior of PEG600-incorporated concrete [23-24].

### 2. Tests and methods

#### 2.1. Materials

The phase transition temperature of PEG-600 is 16.81°C (solid phase line) to 19.81°C (liquid phase line), and PEG-600 undergoes phase transition in either the winter or summer operating mode of the energy pile. Table 1 represents the thermophysical properties of the PCM, the DSC3500 differential scanning calorimeter from NETZSCH Instruments is designated as a measuring instrument.

#### 2.2. Phase change aggregate preparation

##### 2.2.1. PCM-HSB preparation

Sustainable construction materials have garnered considerable attention due to environmental concerns and the demand for energy-efficient buildings. Concrete, being the most widely used construction material, has been the focus of numerous studies aimed at enhancing its sustainability and functional properties. Their incorporation into building materials is a promising approach to improve thermal regulation and reduce energy consumption in buildings [14]. Among various PCMs, **Polyethylene Glycol (PEG)**, particularly PEG600, is favored for its suitable melting point (around 20–30°C), chemical stability, and non-toxicity. Studies by [15] demonstrated that PEG-based PCMs effectively stabilize indoor temperatures by storing excess heat and releasing it [16].

**Table 1: Properties of PEG600 used in this study.**

Items	Values Solid	Liquid
Kinematic viscosity(mm <sup>2</sup> s,99°C)	9.8	-
Thermal conductivity (W/m· °C)	0.25	0.22
Latent heat (J/g)	105.4	-
Density (kg/m <sup>3</sup> )	1350	1247
Specific heat capacity (J/g· °C)	1.85	1.67
Phase change temperature (°C)	15.47	18.68



(a) PEG600 (b) Guar gum (c) Cement Fig. 1. Test materials.

### 3. Results and discussions

#### 3.1 Compressive strength

Fig. 2 shows the compressive strength of GG-PEG-HSB concrete at various GG admixtures and PCM-HSB replacement rates. The compressive strength of concrete attenuates with increasing PCM-HSB substitution rate. P20G1.3 and P22.5G1.3 compared to P25.0G1.3 Compressive strength values decreased by 2.47% and 7.36%, respectively.

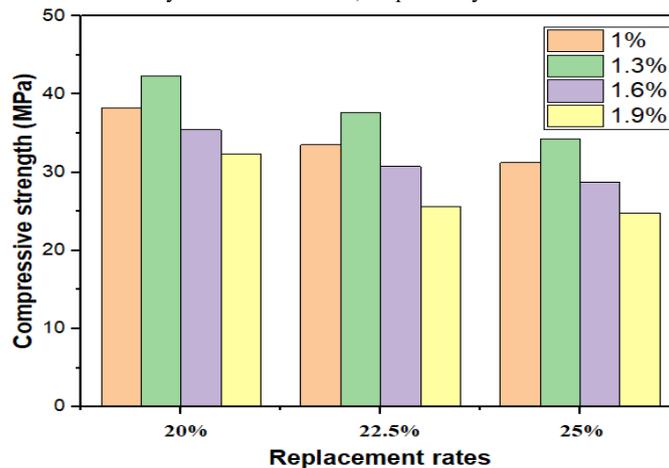


Fig. 2. Compressive strength of GA-PEG-HSB concrete.

#### 3.2 Thermal conductivity

Fig. 3 shows the thermal conductivity of GG-PEG-HSB concrete at various GG admixtures and PCM-HSB replacement rates. At a constant amount of GG, the thermal conductivity of the concrete with PCM-HSB is decreased compared to that of plain concrete.

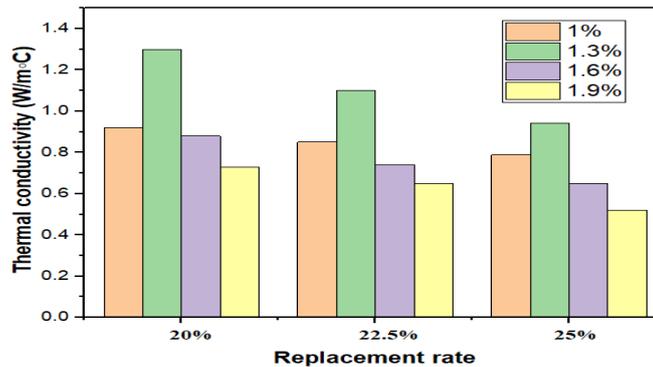


Figure 3. Thermal Conductivity Vs Replacement rate

Fig. 4 shows the results of the specific heat capacity test for GG-PEG-HSB concrete at heat absorption and exothermic. The effect of GG on the specific heat capacity of concrete is minimal.

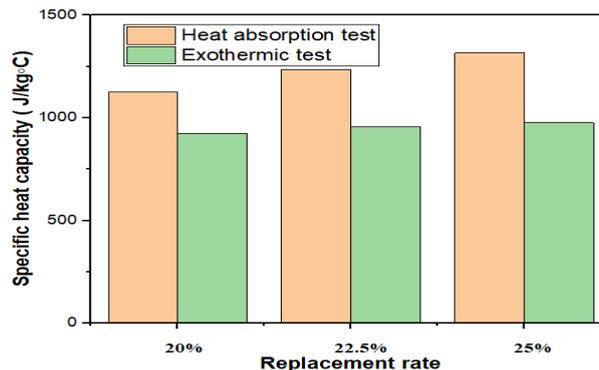
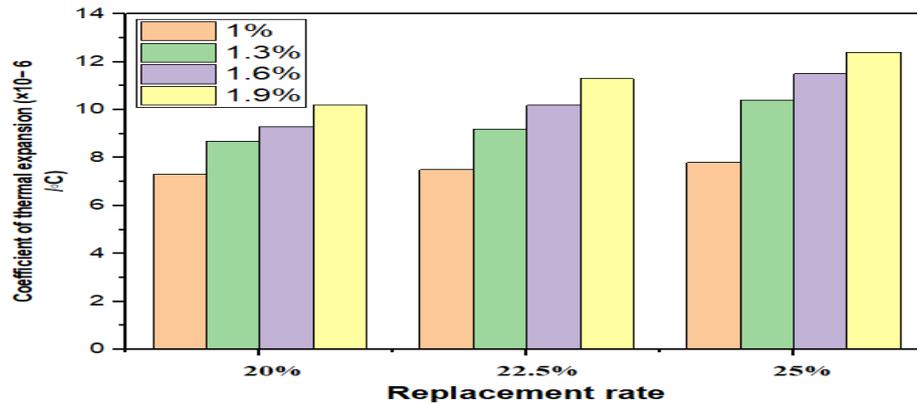


Fig. 4. Specific heat capacity of GA-PEG-HSB concrete.

### 3.3 Coefficient of thermal expansion

Energy piles are affected by extra temperature stresses during operation. This results in a mechanical pile response that is detrimental to superstructure stability. Therefore, it is essential to investigate the coefficient of thermal expansion (CTE) of GG-PEG-HSB concrete. The GG-PEG-HSB concrete thermal expansion coefficient test results are shown in Fig. 5.



### Conclusion

This study explored the incorporation of Polyethylene Glycol 600 (PEG600) as a Phase Change Material in sustainable concrete to evaluate its effects on mechanical strength and thermal behavior. The results indicate that:

- Adding PEG600 improves the thermal regulation capability of concrete by effectively absorbing and releasing heat during temperature fluctuations, contributing to enhanced energy efficiency in building applications.
- While PEG600 incorporation leads to a slight reduction in compressive strength compared to conventional concrete, the strength values remain within acceptable limits for non-structural and certain structural uses.

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