Cycle performance of a novel Thermal Energy Storage (TES) system based on geopolymers from Construction and Demolition Waste

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1. Introduction

Thermal energy storage (TES) technologies offer a viable large-scale heat storage solution, with sensible heat storage being the simplest and more economical among them. In sensible TES systems, Ordinary Portland cement (OPC) concrete-based materials predominate; however, their use is limited to low-temperature applications, due to the thermal degradation of OPC that occur at about 400 °C. In this work, the concept of an innovative sensible TES modular system based on geopolymers (GeoTES) from Construction and Demolition Waste (CDW) is presented and the thermal energy storage capacity of a lab-scale GeoTES sample is evaluated in charging / discharging cycles at temperatures higher than 400 °C.

2. Experimental / Methodology

The production of the lab-scale GeoTES sample (module) was based on WB supplied from a CDW recycling plant in Cyprus, metakaolin and an aqueous solution of 7 M NaOH. Details regarding the raw materials' chemical composition and the experimental procedure followed are given in previous work [2]. The Geo-TES module had dimensions of 10x10x25 cm^3. During a batch charging / discharging cycle, the Geo-TES module was heated for 6 hours to a constant temperature (400, 500, 600 and 700 °C) using a heating element and then, left to cool to ambient temperature. Each cycle lasted approximately 24 hours, during which real-time temperature measurements were taken via thermocouples placed near the heating element at the core of the Geo-TES module and at two points on its surface.

3. Results and Discussion

As shown in Figure 1(a), a rectangular geometry was selected for the GeoTES system unit, as it provides structural simplicity and mechanical stability, allowing scalability and modularity. Furthermore, the large flat contact surfaces created between modules enhanced heat transfer, while minimizing thermal losses.

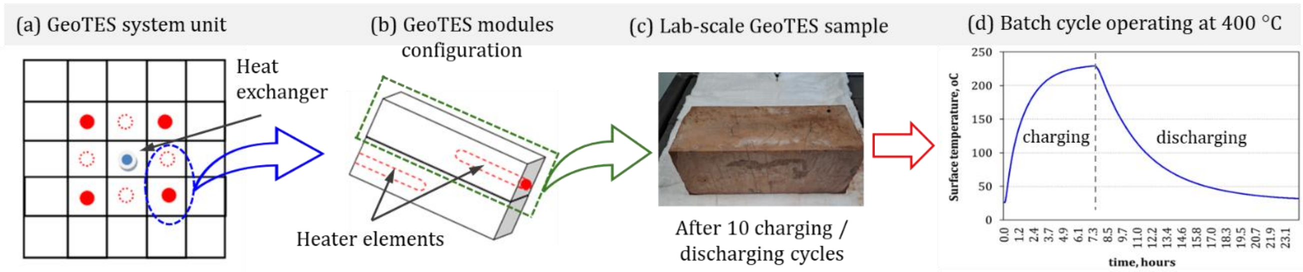

Figure 1. Cross-section of the GeoTES modular system unit (a); GeoTES modules configuration (b); Lab-scale GeoTES sample (c) batch cycle operating at 400 °C.

However, significant heat losses ranging between 40% and 45% were observed during charging (Figure 1d), mainly attributed to inadequate thermal insulation. Heat losses were reduced by almost 10% through the addition of a second thermal insulation layer to GeoTES sample. As shown in Figure 1(c), after 10 operating cycles, the GeoTES sample remained durable, without structural damage or deformations. Based on the experimental results, the volumetric energy storage capacity of the innovative GeoTES system was calculated to 1.5 $MJ/m^3 \cdot °C$, which is comparable to that of OPC concrete-based products (1.7 – 2.0 $MJ/m^3 \cdot °C$).

4. Conclusions

This study proposed a novel concept for a geopolymer-based sensible TES modular system produced from CDW, which was proven promising for high temperature applications. The GeoTES sample was tested in batch charging / discharging cycles at temperatures up to 700 °C and managed to maintain its structural integrity. Its volumetric energy storage capacity was approximately 1.5 $MJ/m^3 \cdot °C$, with the key limitations being thermal losses. Improving thermal insulation substantially reduced the thermal losses of the GeoTES module.

5. References

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