THERMAL PROPERTIES EVALUATION OF PCM AND BIOCHAR APPLIED INTERIOR FINISHING MATERIALS

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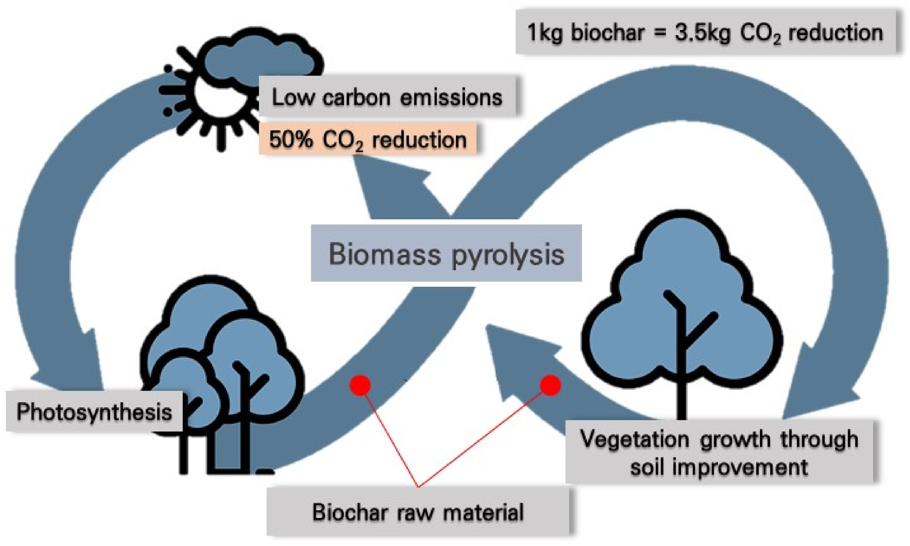
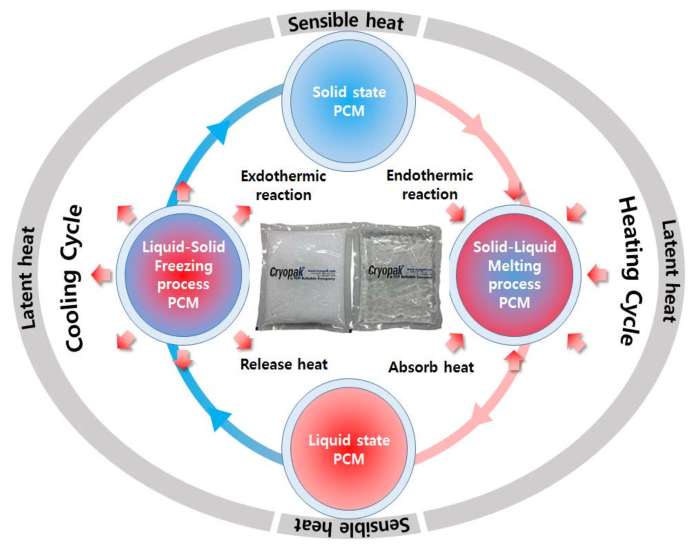
Abstract

This biochar is a porous carbon material produced through thermochemical conversion of organic materials under oxygen-depleted conditions. Adding biochar to building materials can store and fix carbon in structures for decades, and this carbon sequestration helps to balance the global carbon cycle. A PCM is a latent heat thermal energy storage material that can store and release heat as heat of fusion or solidification during the phase change process. This experiment aims to improve the thermal performance of artificial stone finishes used as interior veneers. A phase change material (PCM) with a high latent heat performance and biochar, an eco-friendly material, were used in the experiment. n-Octadecane was incorporated into lightweight aggregates; spruce tree(ST), rise husk(RH), and miscanthus straw(MS) biochars were utilized. The fabricated specimens exhibited clear peak temperature and latent heat values depending on the PCM used. In terms of strength characteristics, the specimens with biochar up to 4% showed equivalent or higher compressive strength to those without biochar, and the use of 6% biochar was associated with a decrease in strength. In addition, the thermal conductivity of the specimen decreased as more biochar was mixed, and it was found to decrease in the order of RH, ST, and MS biochar. Through the heat transfer test, the heat storage performance of the specimens and the temperature delay effect (of approximately 2.7 h) were verified. When using ST, RH, and MS biochars, the peak temperature decreased by approximately 4–5 °C compared to the PAS test sample without biochar. An artificial stone with an integrated PCM can be effectively used for peak temperature control based on the heat storage performance. When an appropriate amount of biochar is applied, a consistent level of strength can be maintained and the thermal conductivity can be improved. The appropriate proportion of biochar was found to be within 4% of the weight of the cement. Using biochar that reuses waste provides an environmental advantage, and a biochar specimen can enable efficient use of thermal energy and room temperature control.

Research Background

- Biochar is a porous carbon material produced through the thermochemical conversion of organic matter under oxygen starvation conditions. Biochar is considered an environmentally friendly material because it is produced using biomass and waste from agriculture, forestry, etc. Adding biochar to building materials can store and fix carbon in structures for decades, and this carbon sequestration helps balance the global carbon cycle. Therefore, the use of biochar as a building material can provide significant environmental benefits. Biochar is mainly integrated with cement materials in construction-related studies because of its excellent chemical stability. A phase change material (PCM) is a latent heat energy storage material capable of storing and releasing heat as heat of fusion or heat of solidification during phase change.
- Applying PCM to buildings is one of the ways to reduce building energy by using passive technologies of buildings. When PCM is applied to a building, it can absorb heat by changing the phase during the day and mediate the temperature through an exothermic process at night. Therefore, it can help to improve thermal comfort by lowering the temperature amplitude and correcting the maximum. Applying such PCM to building finishing materials with a large surface area can be effectively utilized to control building energy. In this study, an artificial stone finish was prepared by mixing spruce (ST), rise husk (RH) and silver grass (MS) biochar with cement and impregnating the artificial lightweight aggregate with PCM.





Materials and Methods

- **Materials**

- The PCM used in this study was organic paraffin, n-Octadecane (C18H38). In addition, lightweight fine aggregates were used for morphological stabilization of PCM. The size of lightweight fine aggregate is 1.2~5mm and the density is 1.77g/cm2, which is about 32% lighter than natural sand due to the internal pores. The integration of PCM and lightweight fine aggregates is manufactured by vacuum impregnation. RH and MS biochar was prepared at a pyrolysis temperature of 550 °C using an experimental scale pyrolysis machine. The pyrolysis temperature was obtained by burning at 550°C for about 12-17 minutes, and the Biochar is ground and mixed into the binder.

Table 1. n-Octadecane properties

PCM	Phase change temperature (˚C)	Thermal conductivity (W/m·K)	Latent heat (J/g)
n-Octadecane	28	0.2	241

Table 2. Pore characteristics of Biochar

biochar	Surface area (m2/g)	Total pore volume for pores with diameter (cc/g)	Average pore diameter (nm)
Spruce tree(ST)	235.1	0.136	2.31
Rise husk(RH)	13.77	0.333	9.67
Miscanthus straw(MS)	17.03	0.027	6.33
xGnP	655.1	1.218	7.43

- **Preparation of specimens**

- Each specimen consisted of a mixture of water, cement and each aggregate in a weight ratio of 0.5:1:2.5. For the artificial stone (AS) specimen, natural sand was used, and for the lightweight artificial stone (LAS) specimen, lightweight aggregate was used. PCM artificial stone (PAS) specimens were prepared using lightweight aggregate impregnated with PCM. Table 1 lists the mixing ratios of the specimens.
- To examine the characteristics of the specimen, compressive strength and thermal conductivity were measured. Thermal conductivity was measured using the heat flow method. In order to confirm the latent heat performance and heat transfer effect of the PCM-mixed specimen, a dynamic heat transfer test was performed using a heating film. The heating film was heated at 50 °C for 6 h, free-cooled for 6 h, and temperature data were collected using a data logger.

Table 2. Pore characteristics of Biochar

Mix	Water	Binder (W*%)					Aggregate
		Cement	ST	RH	MS	xGnP	
AS	0.5	100	-	-	-	-	Natural sand
LAS	0.5	100	-	-	-	-	Lightweight aggregate
PAS	0.5	100	-	-	-	-	PCM-lightweight aggregate
ST2	0.5	98	2	-	-	-	PCM-lightweight aggregate
ST4	0.5	96	4	-	-	-	PCM-lightweight aggregate
ST6	0.5	94	6	-	-	-	PCM-lightweight aggregate
RH2	0.5	98	-	2	-	-	PCM-lightweight aggregate
RH4	0.5	96	-	4	-	-	PCM-lightweight aggregate
RH6	0.5	94	-	6	-	-	PCM-lightweight aggregate
MS2	0.5	98	-	-	2	-	PCM-lightweight aggregate
MS4	0.5	96	-	-	4	-	PCM-lightweight aggregate
MS6	0.5	94	-	-	6	-	PCM-lightweight aggregate
xGnP6	0.5	94	-	-	-	6	PCM-lightweight aggregate

Results and Discussion

- **Thermal conductivity analysis**

- In the case of specimens using PCM-integrated artificial fine aggregate, the overall compressive strength decreased by 2 to 5 MPa, but all of them satisfy the required strength. The thermal conductivity is 0.9521 W/m·K for the AS specimen using natural sand and 0.6711 W/m·K for the PAS specimen using PCM impregnated aggregate. The LAS and PAS specimens have lower thermal conductivity than the AS specimens, which is thought to be due to the pores of the aggregates used. For biochar-based specimens, the overall thermal conductivity level is lower than for PAS specimens. In particular, RH biochar has the lowest thermal conductivity.

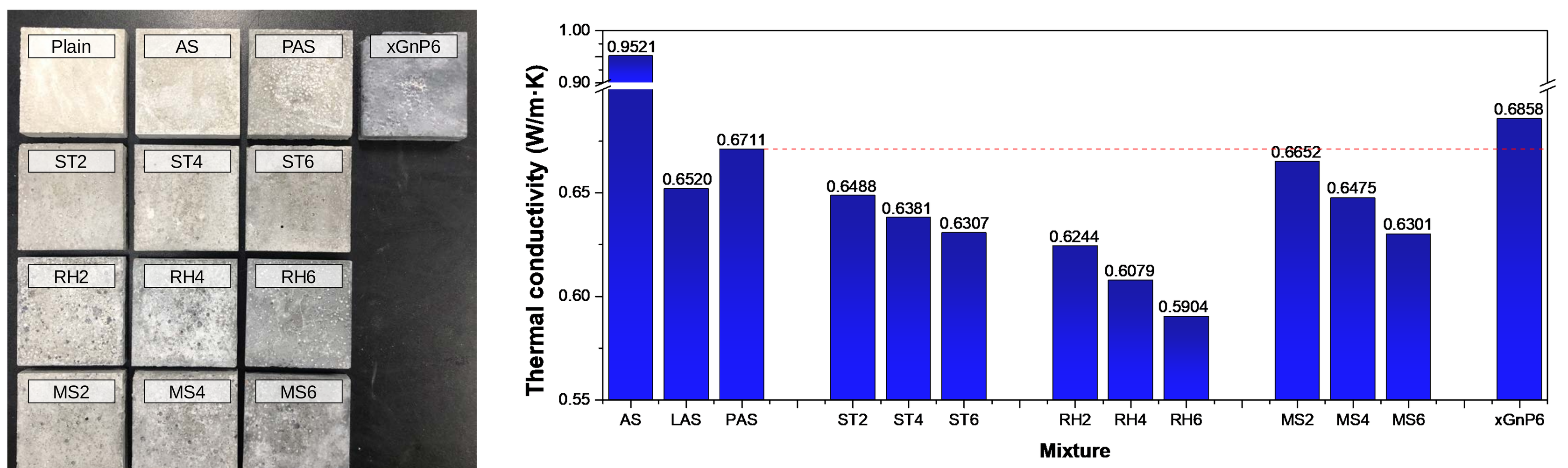


Figure 1. Results of thermal conductivity test

- **Dynamic heat transfer analysis**

- A dynamic heat transfer analysis was performed to evaluate the thermal properties of the PCM-integrated artificial crushed bricks. As a result of the test of the specimen heated at 50°C for 6 hours and free-cooled for 6 hours, the maximum temperature of the PAS specimen was delayed by about 2.7 hours for the PCM specimen, and the maximum temperature was 1.7°C higher than that of the AS specimen. This is a characteristic of the specimen using PCM, and it can be seen that the heat rising to the maximum temperature is delayed due to the latent heat of PCM. In addition, specimens with PCM during cooling exhibit a thermal lag time of approximately 4 hours.

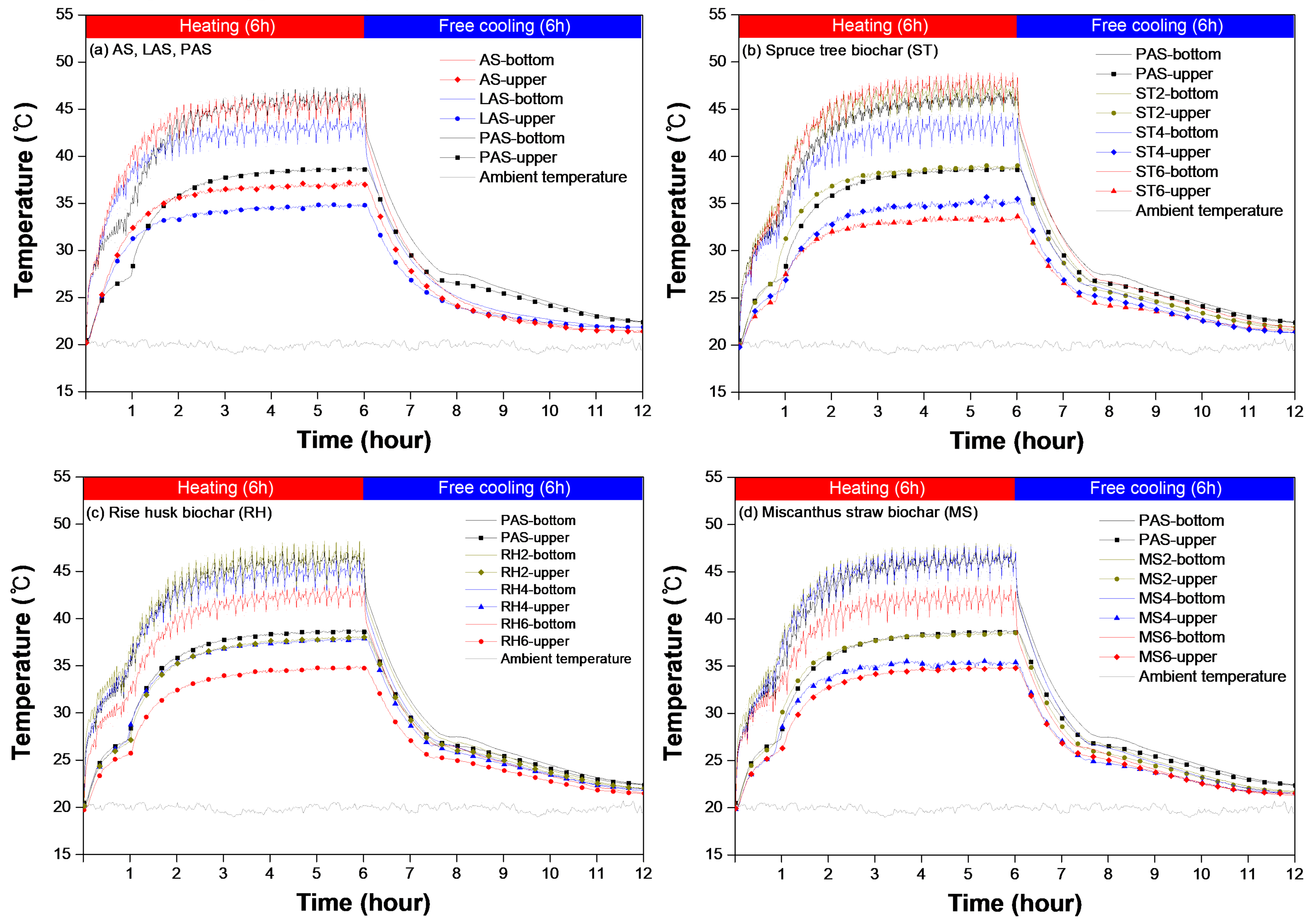


Figure 2. Results of dynamic heat transfer analysis (a) AS, LAS, PAS (b) ST biochar (c) RH biochar (d) MS biochar

- **Differential scanning calorimetry analysis**

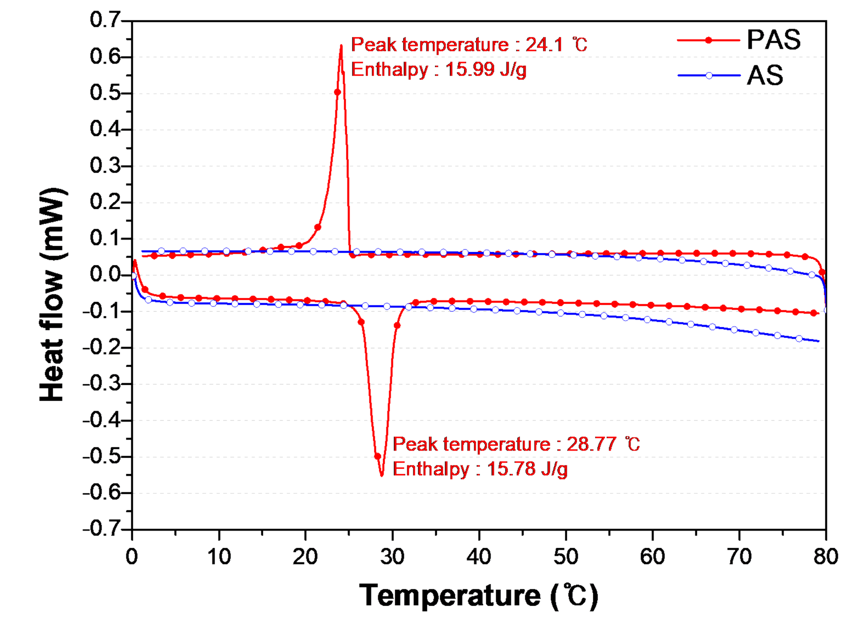


Figure 3. Results of DSC analysis

- **Thermal imaging camera analysis**

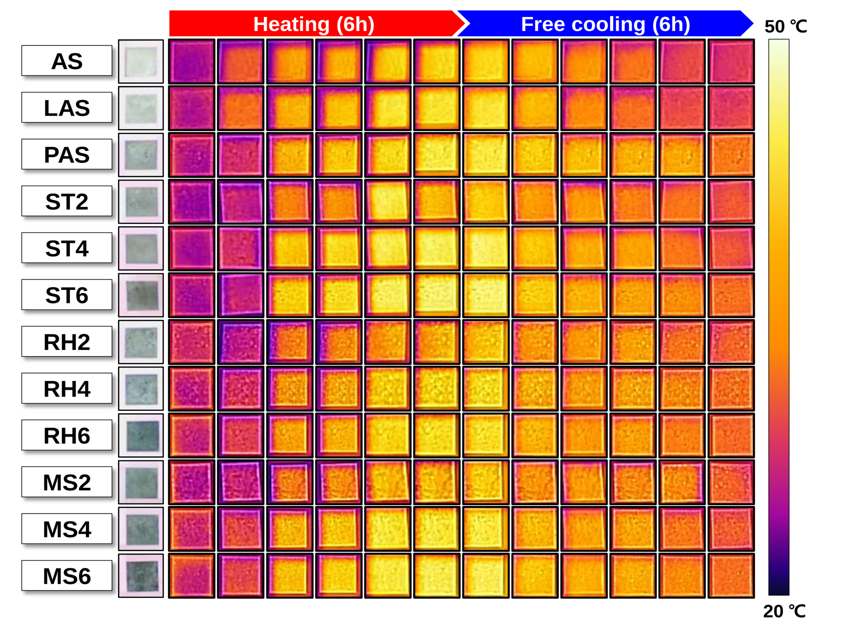


Figure 4. Images of surface temperature behavior

Conclusion

- In this study, biochar and PCM were integrated to improve the thermal performance of artificial stone used as a building finishing material. The fabricated specimen showed a clear peak temperature and latent heat value depending on the PCM used. When biochar was blended, the peak temperature was reduced by approximately 4-5 °C compared to the test sample without biochar. Artificial stone with integrated PCM can be effectively used for peak temperature control based on thermal storage performance. There are environmental benefits to using biochar that reuses waste, and biochar specimens allow for efficient use of thermal energy and control of room temperature.

Acknowledgements

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