Optical and thermal behavior of Phase-Change Fibers for enhancing thermal comfort

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Introduction

Climate change and the Urban Heat Island (UHI) effect have increased thermal discomfort and energy demands in cities. Phase-Change Materials (PCMs) offer a sustainable solution by absorbing and releasing latent heat. This study develops Phase-Change Fibers (PCFs) via wet-spinning, using cellulose acetate (Mn 30,000) as the protective sheath and Polyethylene glycol (PEG 400 or 600) as the core, aiming to enhance thermal performance in civil engineering materials.

Objectives

- Development of Phase-Change Fibers (PCFs);
- Characterization of morphology and chemical integration through Bright-Field microscopy and ATR-FTIR;
- Thermal Evaluation of phase change temperatures and enthalpy through DSC and TGA.

Methodology

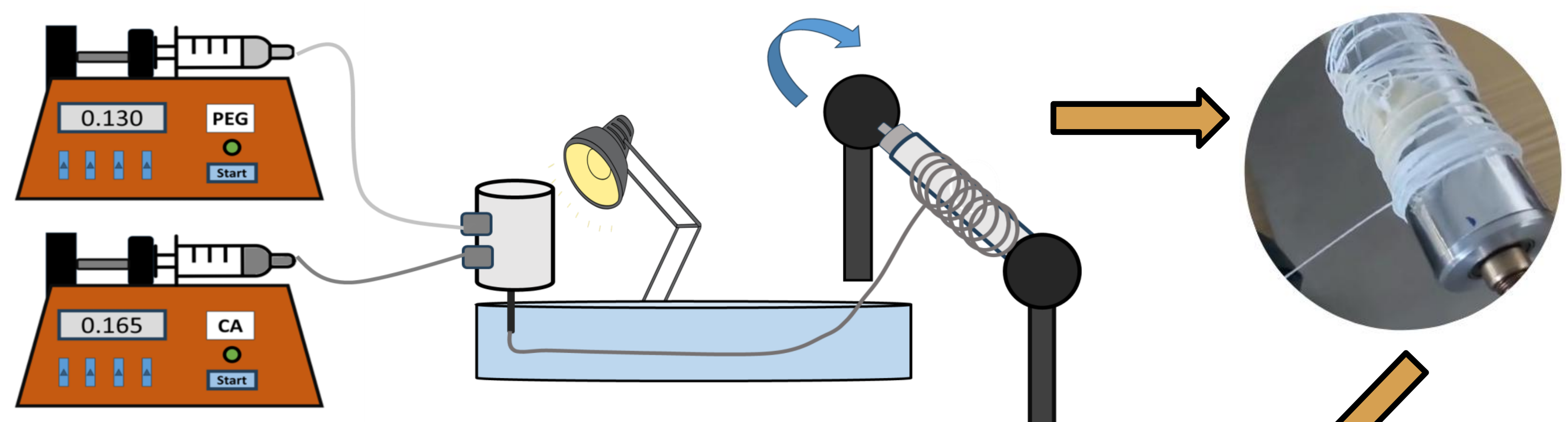
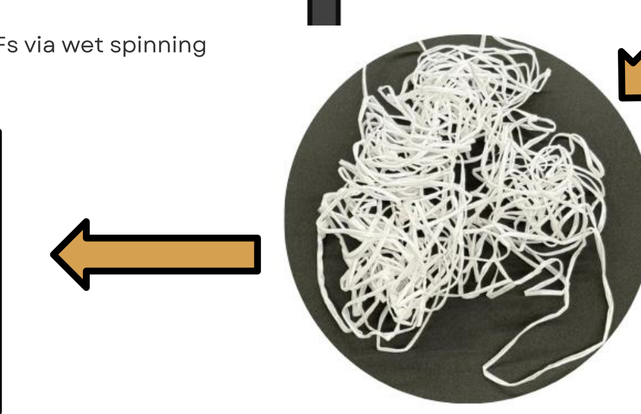


Figure 1- Experimental system to produce PCFs via wet spinning



- 1º Phase – Morphological and Chemical analyses
- 2º Phase – Thermal analyses

Results and discussion

1º Phase – Morphological and Chemical analyses

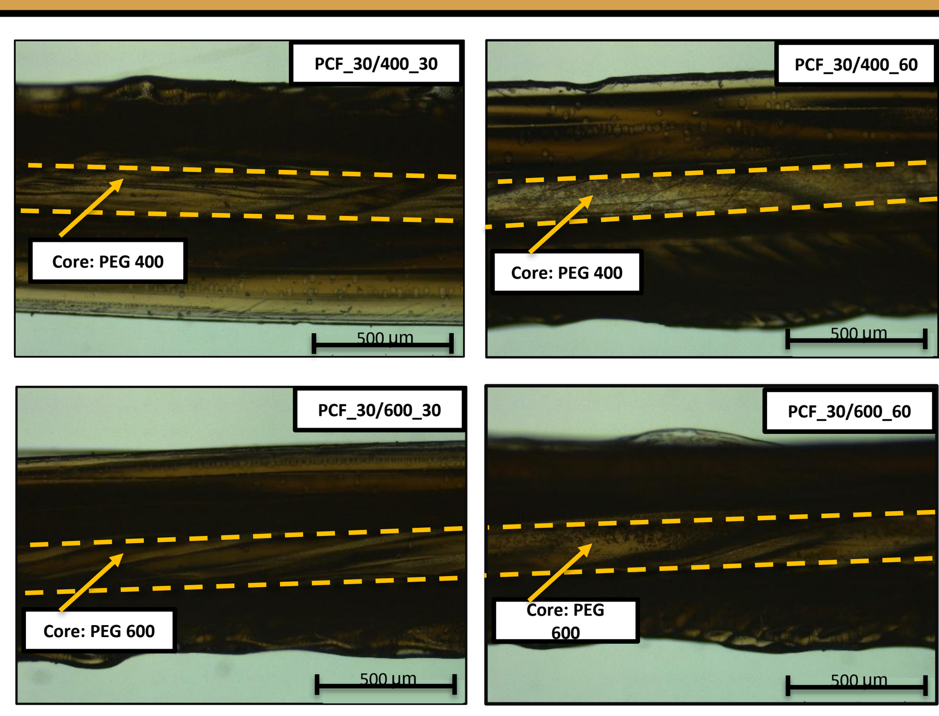


Figure 2: PCFs analyzed at 5× magnification using Bright-Field Microscopy: PCF_30/400_30; PCF_30/400_60; PCF_30/600_30 and PCF_30/600_60

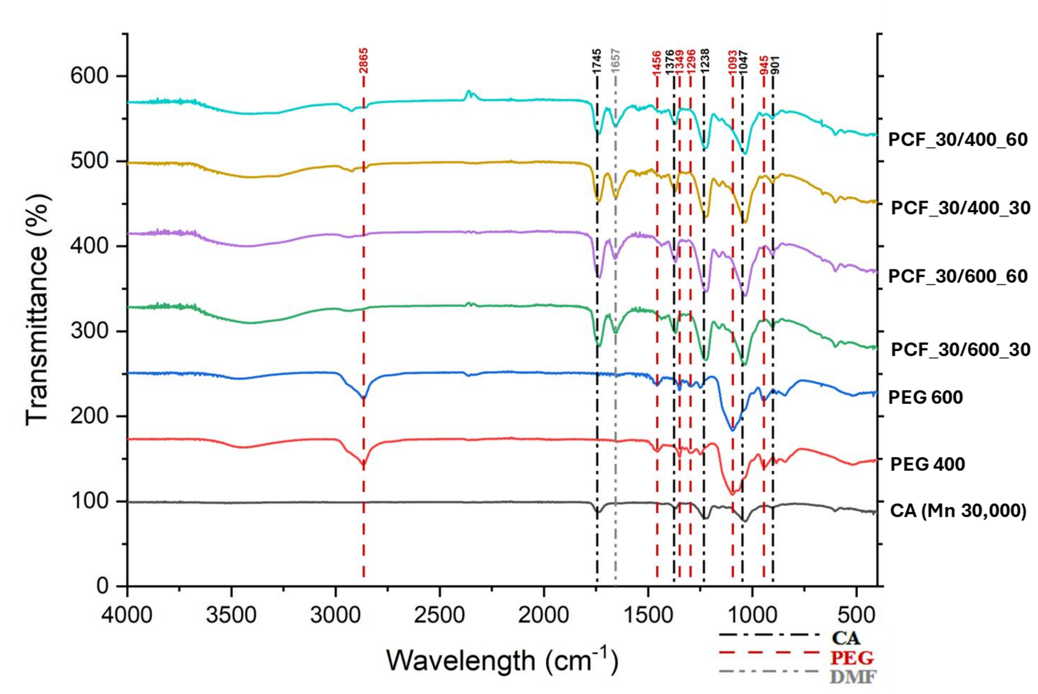


Figure 3: Virgin materials and PCFs analyzed with ATR-FTIR: CA (Mn 30,000, PEG 400, PEG 600, PCF_30/400_30; PCF_30/400_60; PCF_30/600_30 and PCF_30/600_60

2º Phase – Thermal analyses

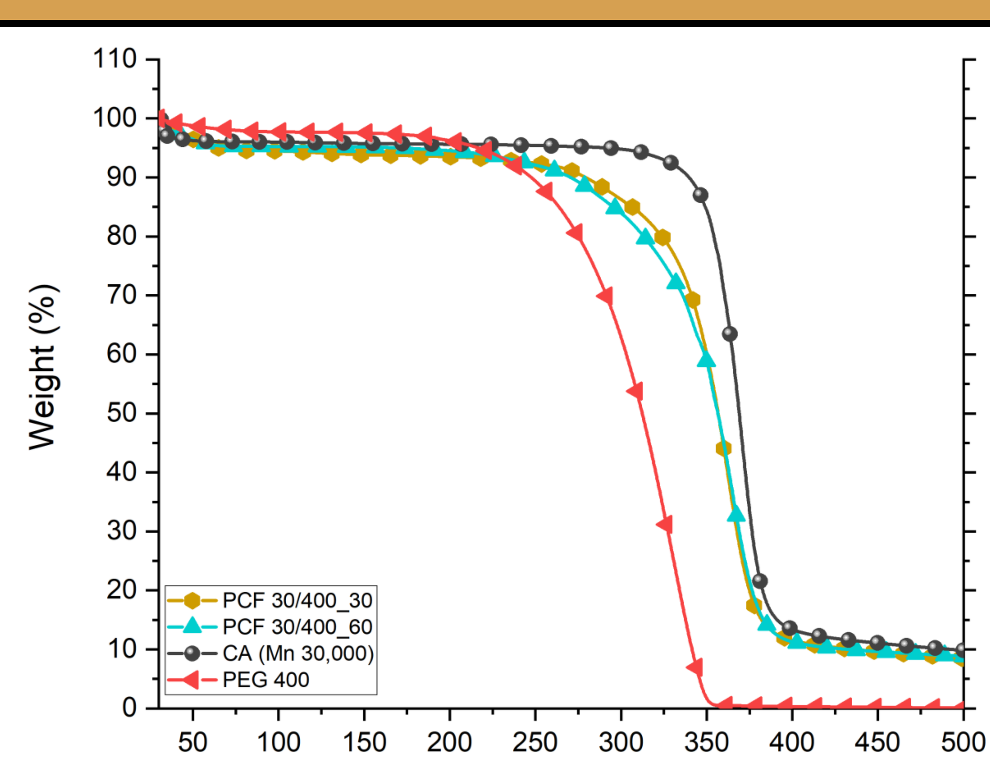


Figure 4: Virgin material and PCFs analyzed by TGA in a range from 30 to 500 °C under a N_2 atmosphere, with a calibrated flow rate of 200 mL/min and exposed to a heating rate of 10 °C/min: CA (Mn 30,000), PEG 400, PCF_30/400_30 and PCF_30/400_60

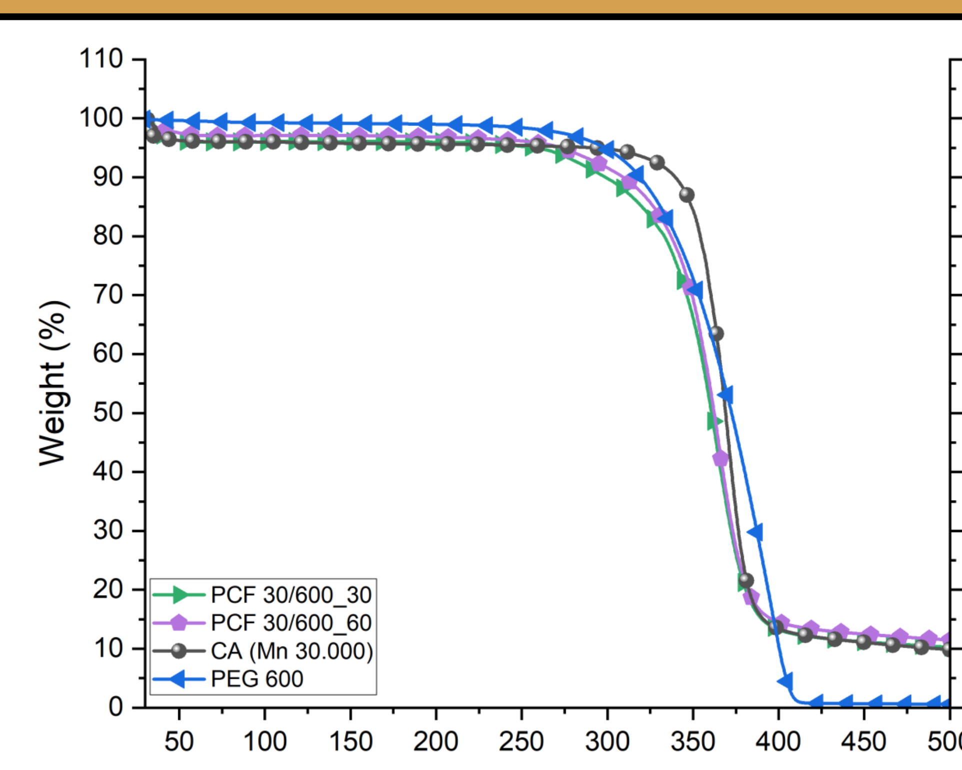


Figure 5: Virgin material and PCFs analyzed by TGA in a range from 30 to 500 °C under a N_2 atmosphere, with a calibrated flow rate of 200 mL/min and exposed to a heating rate of 10 °C/min: CA (Mn 30,000), PEG 600, PCF_30/600_30 and PCF_30/600_60

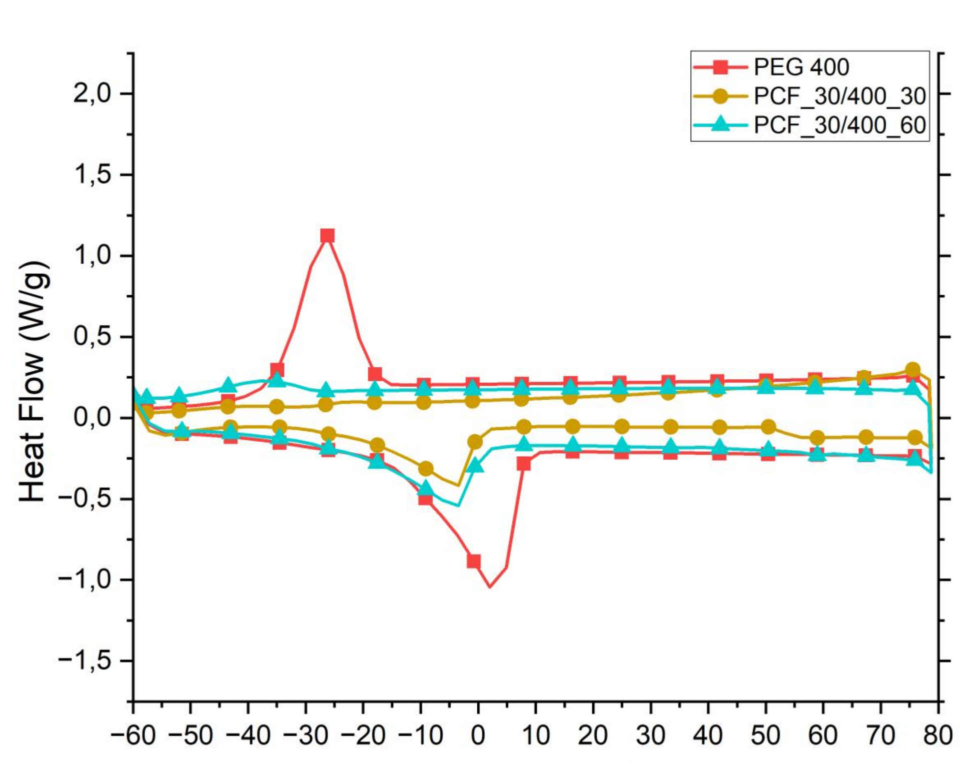


Figure 6: PCFs analyzed by cyclic DSC from 80 to −60 °C under an Ar atmosphere, with a calibrated flow rate of 50 mL/min and exposed to a heating/cooling rate of 10 °C/min: PEG 400, PCF_30/400_30 and PCF_30/400_60

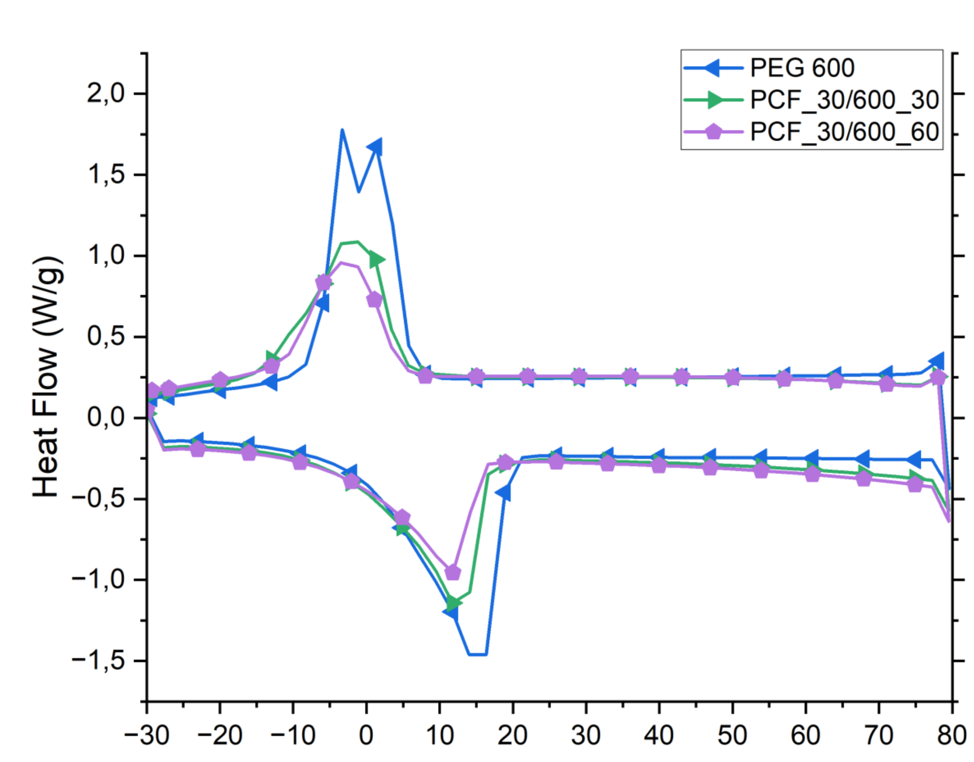


Figure 7: PCFs analyzed by cyclic DSC from 80 to −60 °C under an Ar atmosphere, with a calibrated flow rate of 50 mL/min and exposed to a heating/cooling rate of 10 °C/min: PEG 400, PCF_30/400_30 and PCF_30/400_60

Conclusion

This study successfully developed coaxial Phase-Change Fibers (PCFs) using CA (Mn 30,000) as the sheath and PEG 400 and 600 as the core, via wet-spinning. Structural analysis confirmed the presence of a well-defined core–sheath morphology and the successful chemical integration of the original materials.
The degradation temperatures of ≈ 234 °C (PEG 400) and ≈ 300 °C (PEG 600) confirm their thermal stability and suitability for incorporation into cementitious materials. Moreover, thermal characterization revealed promising phase-change behavior, with PEG 400 and 600 presenting transition temperatures ≈ −4 °C and 12 °C, and endothermic enthalpy values of 26 J/g and 29 J/g, respectively. These results highlight the fibers' capacity for thermal energy storage and regulation. Overall, the PCFs demonstrate great potential for enhancing thermal comfort and energy efficiency in urban construction.

Acknowledgments

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