International Association of Chinese Infrastructure Professionals

THE 13th IACIP Annual Workshop:
Adaptive Infrastructure under Climate Change

Evaluation of Thermal and Rheological Properties of Phase Change Material-incorporated Asphalt Mastic with Porous Fillers

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Introduction

Problem Statement

- Rutting and transverse cracks happen at high and low temperatures and lead to 25.9% and 40% of pavement damages.
- High temperature in asphalt pavements leads to many social and urban issues such as urban heat island (UHI) effect.

Objective

- Explore the feasibility of using phase change materials in asphalt materials in mastic scale by performing rheological and thermal tests

Materials

Two candidates for carrier materials:

- Diatomite (DI)
- Expanded perlite (EP)

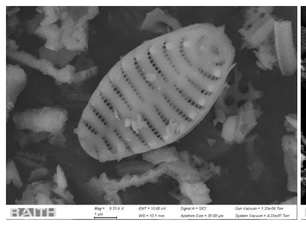
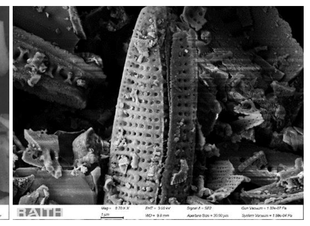
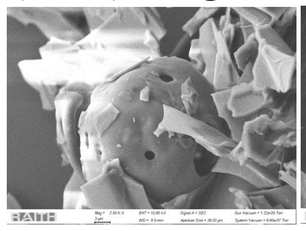
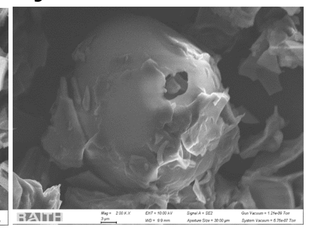

Four candidates for PCMs:

- Polyethylene glycol
- Luric acid
- Paraffin-42
- Paraffin-58

Composite Phase Change Materials Selection (CPCMs)

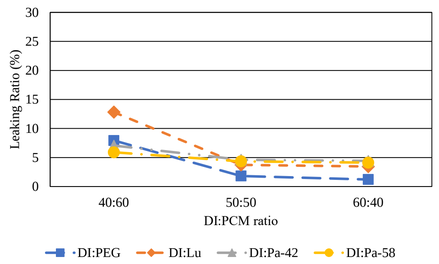
Define three different criteria for CPCM selection:

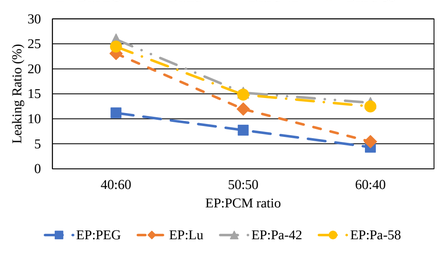
- Scanning electron Microscope (SEM) image analysis

Diatomite: Cylindrical shape, high dense porous structure and large specific surface area
Expanded perlite: Spherical shape, round edges, low number of pores
PCM trapped inside the porous structure of diatomite more efficiently compared to expanded perlite.

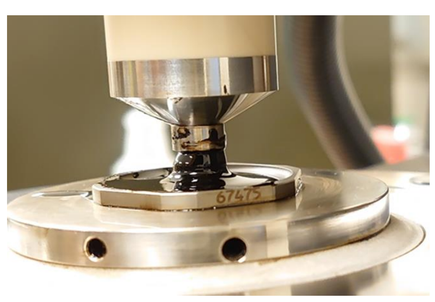
- Filter Paper Test

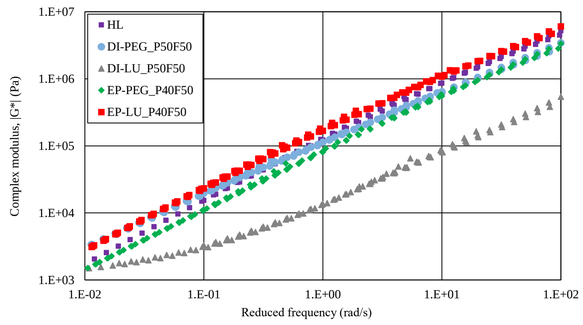




- Master curve by frequency sweep test

Mastic	CPCM	CPCM ratio (Carrier:PCM)	Filler replacement by CPCM
HL (control sample)	-	-	-
DI-PEG_P50F50	DI/PEG	50:50	50
DI-LU_P50F50	DI/LU	50:50	50
DI-Pa(42)_P50F50	DI/Pa-42	50:50	50
DI-Pa(58)_P50F50	DI/Pa-58	50:50	50
EP-PEG_P40F50	EP/PEG	60:40	50
EP-LU_P40F50	EP/LU	60:40	50
EP-Pa(42)_P40F50	EP/Pa-42	60:40	50
EP-Pa(58)_P40F50	EP/Pa-58	60:40	50

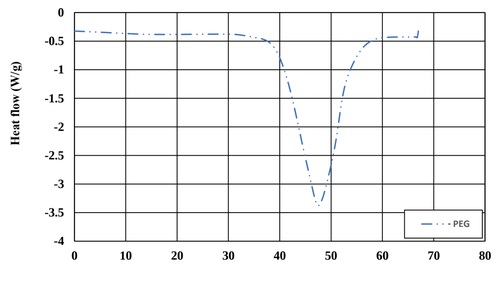


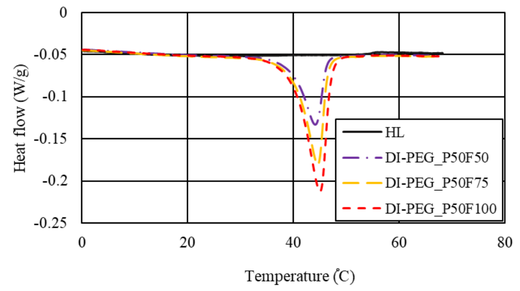


CPCMs	SEM Image	Filter Paper Test	Frequency Sweep Test
DI-PEG_P50	✓	✓	✓
DI-LU_P50	✓	✓	✗
DI-Pa(42)_P50	✓	✓	✗
DI-Pa(58)_P50	✓	✓	✗
EP-PEG_P40	✗	✗	✓
EP-LU_P40	✗	✗	✓
EP-Pa(42)_P40	✗	✗	✗
EP-Pa(58)_P40	✗	✗	✗

Results & Discussion

Differential Scanning Calorimetry Test Results



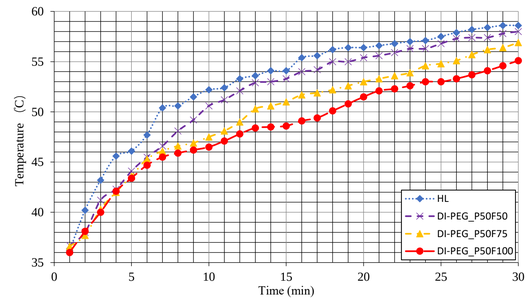


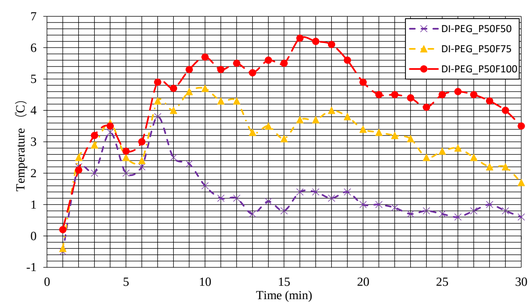
$$\eta(\%) = \frac{\Delta H_{tm}}{\Delta H_{Tm}} \times 100$$

η (%): Efficiency of PCM in modified mastic;
ΔHtm (J/g): Testing enthalpy;
ΔHTm (J/g): Theoretical enthalpy.

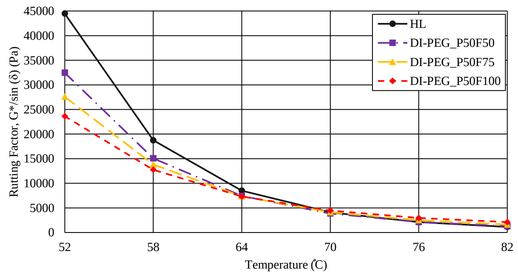
Mastics	Tm (C)	ΔHtm (J/g)	ΔHTm (J/g)	η (%)
PEG	39.8	166.7	-	-
DI-PEG_P50F50	39.7	11	12.52	87.9
DI-PEG_P50F75	40.0	16.9	19.43	87.0
DI-PEG_P50F100	39.9	23.32	26.81	87.0

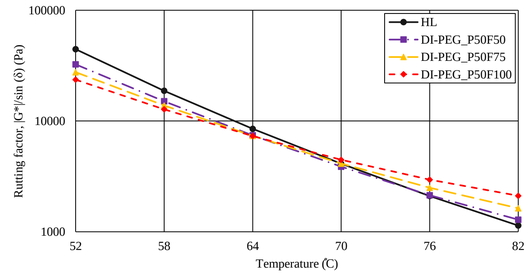
Real-time Temperature Performance

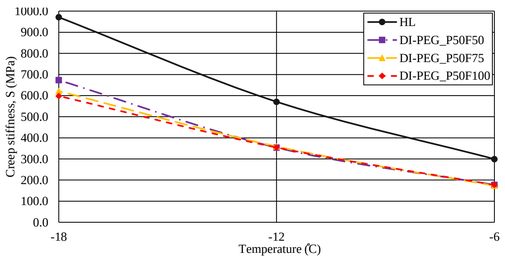


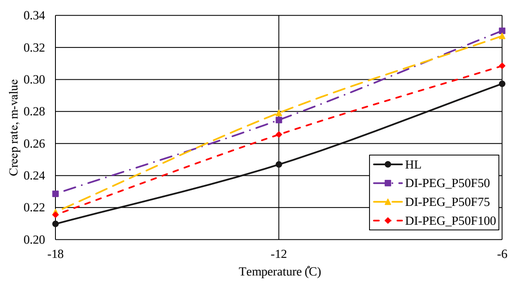


Performance by Superpave factors (G*/sinδ, S, m-Value)









Conclusions

- DSC test showed that the maximum latent heat storage was observed by DI-PEG_P50F100, and real-time temperature performance test confirmed the thermal regulation effect of CPCM on asphalt mastic.
- The rutting factor obtained from the Superpave DSR test suggested that the rutting resistance of modified mastics was lower than the control mastic when the temperature was below 70˚C; the mastics with CPCMs had higher permanent deformation resistance at high temperature.
- The low-temperature BBR tests confirmed that the modified mastics had higher low-temperature cracking resistance.