Reducing the Effects of Low Albedo of Asphalt Materials Incorporating Polyethylene Glycol (PEG) 1000, 2000 and 4000 as Phase Change Materials (PCM)

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Abstract. Albedo plays a vital role in urban microclimates. Civil engineering structures usually absorb a high amount of energy in form of heat, for example asphalt pavements, which have a low albedo, thus contributing to the Urban Heat Island (UHI) effects. Modifying the physical characteristics of asphalt pavements, including reflectance and thermal properties, can help mitigate UHI. The literature points out that one alternative to thermoregulating asphalt materials is the incorporation of phase change materials. Thus, the main goal of this research is to present a systematic review regarding the effectiveness of the incorporation of polyethylene glycol (PEG) 1000, 2000 and 4000 as Phase Change Material (PCM) in asphalt materials. The results showed that incorporating PEG into asphalt materials can regulate heat storage, promoting stability and reducing UHI effects. PEG2000 was more frequently used. PEGs can reduce between of 3.5 and 4.2ºC of the asphalt materials when compared to the conventional ones.

1 Introduction

Albedo of urban surfaces is a critical parameter to characterize the microclimate phenomena, representing the reflected-to-incident solar energy ratio, Figure 1. High-albedo surfaces reflect more sunlight and absorb less heat, while low-albedo surfaces absorb more heat. Building and pavement materials significantly impact albedo and urban heat absorption (1).

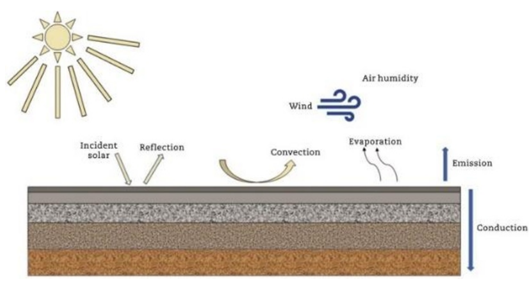

Figure 1: Heat transfer in pavements (1).

Asphalt, commonly used in road pavements, has a low albedo, absorbing solar energy and contributing to the Urban Heat Island (UHI) effects.
Incorporating phase change materials (PCM) can thermoregulate them and mitigate these problems (2). PCM absorb and store thermal energy during temperature increases and release it when temperature decreases (1). Among the available PCM, Polyethylene glycol (PEG) is one of the most used in asphalt pavements (3). PEGs present high latent heat capacity, suitable phase change temperature, and high thermal and chemical stability and offer environmental benefits since they are non-toxic (4,5). Thus, this research aims to conduct a systematic review to evaluate the effectiveness of PCM, PEG 1000, 2000 and 4000, in reducing pavement temperature and consequently mitigating Urban Heat Island (UHI) phenomenon.

2 Methodology

A systematic review was conducted using Google Scholar with search terms "PCM," "asphalt," and "Urban Heat Island." Out of 44 articles, only those employing PEGs 1000, 2000, and 4000 as PCM were selected after examining abstracts. The final database comprised 14 documents, focusing on performance aspects and thermal properties of asphalt materials with these PEGs. Although limited to a single database, the search captured significant research in the field.

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3 Results

Table 1 presents for each PEG type the temperature drops of the asphalt material with PEG compared to conventional asphalt material and the literature reference. PEG 4000 contributed to an average temperature reduction of 4.2 ºC, PEG 2000 led to a slightly lower mean decrease of 3.5 ºC and PEG 1000, with one result, reduced 4 ºC.

Table 1. PEG's uses founded in the systematic review.

PEGs	Temperature drops of the asphalt material (ºC)	Reference
4000	3.0	(3)
1000, 2000 and 4000	Not positive effect	(6)
2000	3.15	(7)
2000	5.12	(8)
2000 and 4000	2.2 and 3.0 respec.	(9)
2000	Between 1.5 and 3.3	(5)
2000	Decrease (nve*)	(10)
2000	5.1	(11)
4000	Between 4.5 and 9.0	(12)
4000	Between 0.8 and 5.0	(4)
4000	4.3	(13)
2000	Decrease (nve*)	(14)
2000	4.0	(15)
1000	4.0	(16)

*nve = No value was specified

Despite the temperature reduction not being particularly significant, PEG2000 is the most used PEG. The preference between PEG 2000 and 4000 might be related to molecular weight and melting point differences. Due to its higher molecular weight and viscosity, PEG 4000 is more challenging to handle, making the PCM composite preparation problematic. Additionally, molecular weight affects the phase change temperature, rendering PEG 4000 unsuitable for specific geographical locations owing to its elevated temperature. During the summer, asphalt pavements can reach high temperatures close to PEG 4000's melting point (58 to 61 ºC), complicating the pavement's ability to maintain lower temperatures.

In contrast, PEG 2000 exhibits a phase change temperature between 53 and 55 ºC, making it more effective. The scenario with PEG 1000 is the reverse. With a phase change temperature between 35-40 ºC, it may struggle to maintain low temperatures for long periods as the pavement commonly heats up at higher temperatures. As such, the asphalt pavement with PEG 1000 will store a lot of energy during the morning and release it at night, causing a reverse process and intensifying the urban heat island (UHI) effects. However, the release of heat during the night might not necessarily be detrimental, depending on the latitudes and specific conditions of the location.

4 Conclusions

This systematic review emphasizes PEG 1000, 2000, and 4000's effectiveness in lowering pavement temperatures and mitigating urban heat island effects. PEG 2000 is preferred due to its molecular weight, phase change temperature, and ease of handling. Integrating PCMs like PEG 2000 into asphalt enables urban areas to manage heat storage and absorption effectively, directly influencing albedo measurements and fostering sustainable urban environments. Continued research on improved pavement materials can help tackle the increasing urban heat island issue.

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