Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 14 (2016) 704 – 713

Transportation Research Procedia

www.elsevier.com/locate/procedia

6th Transport Research Arena April 18-21, 2016

Hydronic pavement heating for sustainable ice-free roads

Bijan Adl-Zarrabi [a,]*, Raheb Mirzanamadi [a], Josef Johnsson [a]

[a]*Chalmers University of Technology, Gothenburg, SE-412 96, Sweden*

Abstract

Hydronic pavement is an alternative method for de-icing of roads. A hydronic pavement (HP) could be more environmental friendly than traditional de-icing methods such as salting. The HP system consists of embedded pipes in the pavement structure, with a fluid as energy carrier. The performance of a HP system strongly depends on a number of parameters e.g. the location of the pipes, the thermal properties of pavement structure and the temperature level of the heat storage system. In this paper initial results related to the designing of a HP system are presented.

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)

Keywords: Melting of Ice and Snow; Hydronic Pavement Heating; thermal properties of pavement; asphalt; seasonal energy storage

1. Introduction

Driving on a slippery road pavement could be unsafe and dangerous. The situation might get even harsher in some particular sections of the road like slopes, curves and bridges. To mitigate the slippery conditions, a well-known method is to spread out salt and sand on a road surfaces. A negative effect of spreading salt and sand is the polluting effect of the surrounding environment along the road. In 2014, the consumption of salt and sand used for

* Corresponding author. Bijan Adl Zarrabi. Tel.: +46 31 772 19 88.
E-mail address: bijan.adl-zarrabi@chalmers.se

Peer-review under responsibility of Road and Bridge Research Institute (IBDiM)
doi:10.1016/j.trpro.2016.05.336

winter maintenance of roads was around 0.6 and 1.7 million ton in Scandinavia, respectively (Knudsen et al., 2014). Considering the undesired environmental effect as well as the costs related to corrosion of the road infrastructures caused by spreading salt, it is necessary to apply an alternative method with less negative effects.

An alternative method of spreading sand and salt on the slippery road surfaces could be Hydronic Pavement (HP) system using renewable energy. The HP is a system with embedded pipes inside road pavements in which a fluid like brine, oils or glycol-water circulates (ASHRAE, 2003). During sunny days with high solar gains the road surface temperature is high and the fluid gets warm. The energy of the warm fluid is saved in thermal energy storages to be utilized during cold periods for de-icing of a road surface.

Melting snow/ice via embedded pipes is not a new method. In 1948, the earliest system was installed in Klamath Falls, Oregon, USA by Oregon Highway Department which used geothermal energy (Pan et al., 2015). Nevertheless, the innovation of this study is to use renewable energies such as solar energy as the source of energy. The idea to use renewable energies for safe and ice-free road infrastructures was introduced in the paper which was about sustainability assessment of infrastructure elements with integrated energy harvesting technologies (Bijan Adl-Zarrabi et al., 2014,; Sundberg and Lidén, 2014).

In this paper, three different parameters involved in designing of a HP system, the thermal properties of pavement materials, the design of a HP system and seasonal thermal energy storage (STES) were investigated.

2. Measuring Thermal Properties of Asphalt Pavement by Transient Plane Source method

Thermal diffusivity of a pavement is one of important parameter that influence the efficiency of a HP system e.g. a low thermal diffusivity leads to a longer time to achieve a certain temperature level on the surface of the road. Furthermore, a high specific heat capacity will influence the desired amount of energy in a thermal energy storage. Thus, accurate determination of thermal properties of involved materials are essential in a HP system. There are several methods to measure thermal properties of materials at ambient conditions (Adl-Zarrabi et al., 2006; Mamlouk et al., 2005). One of the methods which have become common for measuring thermal properties of materials is transient plane source (TPS). Gustafsson (1991) described the TPS method for thermal conductivity and thermal diffusivity measurements of solid materials. The measurement method is described in ISO22007-2 (International Organization for Standardization, 2015). Furthermore, Pan et al. (2014) used TPS method to investigate influence of graphite on the thermal properties and anti-ageing properties of asphalt binder. In this paper, the suitability of using the TPS method for measuring thermal properties of asphalt was investigated by using different sensor sizes. Furthermore, the assumption whether or not an asphalt sample is an isotropic material was investigated by measuring thermal properties of the sample in different positions and in different depths of the sample.

2.1. Sample preparation results

A cylindrical sample with the radius of 100 mm and thickness of 60 mm was arbitrary selected. The TPS method needs two specimens thus the sample was divided into two specimen with a thickness of 30 mm. Furthermore, the specimens were divided into two new specimens to measure the thermal properties in different depths. The samples were conditioned in the laboratory. Temperature and relative humidity in the laboratory were 22℃ and around 50%. Fig 1 shows the surface of the sample and position of the sensor. Different sensor sizes were used in order to investigate the most proper size of the sensor related to aggregate size. The sample used in these measurements was arbitrary selected; thus, the information about binder and aggregate is missed. However, largest size of aggregate on the surface is measured to 11 mm.

2.2. Measurement results

2.2.1. Sensor size

The results of measured thermal properties of the asphalt pavement sample using different sensor sizes are presented in Table 1. As it is seen from the results, measuring thermal properties of the pavement samples using different sensor sizes offers different results. However, the variation of the results was expected. Small sensor sizes