Construction and Building Materials 180 (2018) 285–290

Contents lists available at ScienceDirect

Construction and Building Materials

journal homepage: www.elsevier.com/locate/conbuildmat

Examining the effect of different super hydrophobic nanomaterials on asphalt pavements

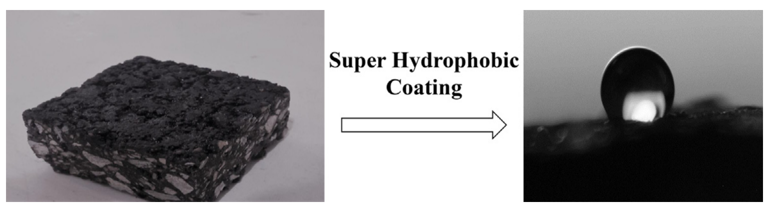
Mahdi Zakerzadeh [a], Sayyed Mahdi Abtahi [a,*], Alireza Allafchian [b], Mohamad Reza Chamani [a]

[a] Department of Civil Engineering, Isfahan University of Technology, Isfahan 84156–83111, Iran
[b] Research Institute for Nanotechnology and Advanced Materials, Isfahan University of Technology, Isfahan 84156–83111, Iran

HIGHLIGHTS

- Investigation into different superhydrophobic coatings on asphalt pavement.
- Measurement the contact angle in the presence of various hydrophobic coatings.
- Selecting the best superhydrophobic material according to contact angle test.
- Obtaining optimum amount of usage selected hydrophobic coating material.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 5 November 2017
Received in revised form 23 April 2018
Accepted 24 April 2018

Keywords:
Super hydrophobic
Asphalt pavement
Contact angle
Nanomaterial

ABSTRACT

Annually large amounts of financial budgets are spent to improve the safety of the roads and airport runways in cold regions. One of the most important parameters in safety and reduction of accidents is the slipperiness of road surface during snowfall. The presence of ice and snow on the surface of the pavement increases the number of road accidents, and also causes the cancellation of flights. Thus, in order to reduce the adhesion of the ice and snow to the pavement and to eliminate them from the surface of the roads, using super hydrophobic coatings instead of traditional winter pavement maintenance methods can be a suitable solution. One of the main methods of detecting and evaluating hydrophobic surfaces is measuring the contact angle of the drop of water with the surface. For this purpose, the contact angle was measured in the presence of various hydrophobic coatings and with a specific weight percentage of sprayed material; and the consumption of 12 g of hydrophobic material was measured on 6 cm $\times$ 6 cm of asphalt samples. By examining the contact angle measured on the asphalt samples with 8 different hydrophobic materials; hydrophobic acrylate W_4 with the chemical formula of (2,2,3,3,4,4,5,5-Octafluoropentyl methacrylate) has the largest angle contact so that on the average it increases the contact angle of asphalt surfaces from 75 to 156, and makes the asphalt pavement surface super hydrophobic.

1. Introduction

Frozen or snow covered roads in cold seasons can easily cause heavy damages such as harming passengers, wasting time and energy, polluting the environment, damaging road pavements, traffic congestion and higher probability of secondary accidents [1]. One of the most common methods of defrosting is using salt and chemicals, which is an obsolete and inefficient method today. Many studies have shown that using these chemical materials seriously affects the performance of asphalt pavement, in addition, it corrodes vehicles and deck bridges and, in the long run, causes the destruction of the environment [2,3]. In recent years, thermal

* Corresponding author.
E-mail addresses: mabtahi@cc.iut.ac.ir (S.M. Abtahi), allafchian@cc.iut.ac.ir (A. Allafchian), mchamani@cc.iut.ac.ir (M.R. Chamani).

https://doi.org/10.1016/j.conbuildmat.2018.04.190
0950-0618/

melting technology (including liquid heating) [4,5], microwave heating [6,7], thermal cables [8] and electrically conductive pavements [9,10] have been widely used to prevent the formation of ice layers on pavements. However, high consumption of energy in these technologies has limited the development and application of these methods since they are not economically optimal [11]. Moreover, rubber particles have been used to pave the coating as anti-ice, which changes the surface of the pavement coating and creates weak areas on the pavement surface [12]. During the process of ice formation on the surface coating, water penetrates the porous surface of the pavement, and then ice crystals form in the pavement texture firmly, and hardly separate from the surface coating. Studies show that low free energy levels is the sign of a super hydrophobic surface that reduces the adhesion of ice to it [13,14]. Accordingly, excessive hydrophobic coatings have been formed to prevent ice adherence to the surface. Static contact angle is one method for detecting and assessing the properties of hydrophobic surfaces with a contact angle greater than 90, indicating that the surface is hydrophobic. Several studies have identified and defined super hydrophobic levels as amounts that have a contact angle of nearly 150 or more [15,16].

There are two main problems in the super hydrophobic levels of asphalt surfaces:

1) To prevent adherence of ice to surfaces, only the hydrophobic state of the surfaces is not enough; rather, a super hydrophobic surface is required [17,18]. That is why a material is needed which, in addition to compatibility with asphalt surfaces (due to the presence of bitumen), has the capability of making a super hydrophobic surface.
2) Super hydrophobic materials are so expensive that using some of them as materials compatible with asphalt surfaces is not economical.

In this research, the contact angle of water in the presence of 8 different hydrophobic materials was evaluated on 60 × 60 mm and 25 mm high asphalt samples. By examining the contact angles, the W_4 hydrophobic material with the chemical formula (2, 2, 3, 3, 4, 4, 5, 5-Octafluoropentyl methacrylate) has had the best performance so that it has made the asphalt surfaces super hydrophobic.

2. Materials and methods of experiment

2.1. Hydrophobic materials

In the hydrophobicity industry, hydrophobic materials are divided into two general categories of water and solvent bases. The hydrophobic bases of water are dissolved in solutions that are soluble in water, and solvent bases of hydrophobic solvents are soluble in solutions whose solvents are hydrocarbon solvents (such as thinner and acetone) [19].

In this study, the following four types of water-based hydrophobic materials were used with abbreviated name: W_1, manufactured by Nanopaya Company, W_2 manufactured by Nano Kasra, W_3 manufactured by Sharifnanopars Co., W_4 made by Sigma-Aldrich Company and two types of solvent-based hydrophobic material with abbreviated names Al_1 made by Nanonia Corporation and Al_2 manufactured by the Nano Kasra Corporation and, respectively, with Commercial names: NPG100, Oligo methyl hydride siloxane, based on nano coating TiO_2, Octafluoropentyl methacrylate, based on nano coating SiO_2 and Methyl siloxane Potassium were also used. Each of the hydrophobic materials has an optimal dissolution rate as shown in Table 1.

It should be noted that some solvent base hydrophobic coating materials cause problems for the asphalt specimens that were not used in the experiment process. In this category of materials, after spraying the hydrophobic material, the bitumen on the surface of asphalt samples is solved in the hydrophobic material and separates them from the sample asphalt coating. The reason for this problem is the presence of hydrocarbon solvents such as acetone and thinner in this type of hydrophobic material that dissolves bitumen in the solution. That is why strong hydrocarbon solvents are not used in the experiments.

2.2. Properties of asphalt used in the experiments

In the present study, experiments were carried out using the asphalt from surface layer, with maximum size of aggregate 12 mm of Sepahan Road Construction Plant, which is commonly used for road construction. The bitumen used to make this asphalt is the bitumen of the Jeyoil Company, with PG64-16, which is used in temperate climates. Table 2 shows the mixing design for this asphalt.

2.3. Plan of the experiment

In this research, the experiment of water droplet contact angle was chosen to determine the best hydrophobic effect on the asphalt coating, and it was tested. To determine the effect of each parameter of the results, a number of asphalt samples were prepared in the size of 60 × 60 mm and thickness of 25 mm. One of the most influential factors in this experiment is the amount of material sprayed on the surface; however, the type of material and the duration of the hydrophobic material curing after spraying material on the asphalt surface are also of great importance. For this purpose, the amount of hydrophobic material sprayed on the surface is experimentally measured at 12 g (the highest amount of consumption is proportional to the sample 60 × 60 mm) for each asphalt sample. For every sprayed material on the asphalt sample surface, three samples were used for coating; for six types of hydrophobic materials with optimal dissolution ratio, 18 asphalt samples were needed, and 3 asphalt samples were used for the control. Totally 21 asphalt samples were needed in the first phase. Then, the best hydrophobic coating material was selected by conducting the contact angle experiment. The selected hydrophobic material was tested with a consumption rate of less than 12 g (9, 6 and 3 g), and the optimum amount of hydrophobic coating material was obtained. The process of laboratory work is summarized as follows:

Asphalt samples were taken from Sepahan Road Construction Plant with maximum size of aggregate 12 mm. Then, the asphalt was compressed by terrazzo tiles pressing machine. In this step, to prevent the mold from sticking to the asphalt, the mold body was completely impregnated with gasoline. After complete formation of the asphalt, samples of 60 × 60 mm were cut with a diamond blade. In the short process, preparation of asphalt samples can be observed (see Fig. 1).

2.4. Hydrophobic samples of asphalt

Hydrophobicity of the asphalt samples with hydrophobic coating materials is such that first, they dissolve the raw material with the dissolution ratio listed in Table 1, with a suitable solvent (water or hydrocarbon solvents); then, the obtained solution is sprayed on its surface. The hydrophobic surface should not be exposed to any material for 24 h until the chemical bond with the coating surface of the pavement is completed. In this study, two curing durations of 2 and 24 h were used to study the effect of time on the formation of nano-sized arrays on the surface and completion of hydrophobic operations. The amount of hydrophobic material coat-

Table 1
Dissolving ratio of hydrophobic materials.

Hydrophobic coating material	W_1	W_2	W_3	W_4	Al_1	Al_2
Dissolving ratio	1/10	1/10	1/10	1/10	Prepared*	Prepared

* The Stype of hydrophobic coating material used in this study is produced with an optimal dissolution rate and a ready-to-use state in the plant.

Table 2
Mixing design for asphalt of Sepahan Road Constructors.

Type of asphalt	Bitumen (weight percent)	Filler (weight percent)	Aggregate 0–6 (weight percent)	Aggregate 6–12 (weight percent)
0–12	4.9	5	65	30