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New achievements on positive effects of nanotechnology zyco-soil on rutting resistance and stiffness modulus of glasphalt mix

H. Ziari, H. Behbahani, N. Kamboozia *, M. Ameri

School of Civil Engineering, Iran University of Science and Technology (IUST), Tehran 16846-13114, Islamic Republic of Iran

HIGHLIGHTS

- N-Zy can improve the stiffness modulus of glasphalt mixtures.
- N-Zy as an anti-stripping agent in glasphalt inhibit rutting performance.
- SEM images shows that specific area of modified bitumen is increased.
- N-Zy improves bitumen stiffness & rutting resistance of glasphalt.
- N-Zy as an anti-stripping agent can improve cohesive between aggregates and glass.

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ABSTRACT

On the basis of previous studies, it has been demonstrated that glass is capable of improving the behavioral characteristics of asphalt mixtures. The purpose of the present study is to assess the effect of nanotechnology zycosoil on rutting resistance and stiffness modulus of glasphalt mixtures through laboratory experiment. For this purpose asphalt samples with two types of graining in their optimal percentage of bitumen were subject to the dynamic tests and their mechanical properties are evaluated. Eventually, observations on the creeping behavior and stiffness modulus of the asphalt samples with two different graining types for the different percentages of waste crushed glass have been presented. The results of the study indicate that the samples of glasphalt modified with nanotechnology zyco-soil show a remarkably better performance as compared to the samples of conventional asphalt.

1. Introduction

1.1. Glasphalt mixture

The pavement of the roads as the surfaces which frequently bear heavy loads should be sufficiently resistant against fatigue, fracturing, creeping and slippage [1]. In order for the mixture of asphalt to be able to perform tasks throughout the lifespan of pavement layer adequately, it should be resistant against the climatic changes and firmly withstand the constant deformations and cracks created as a result of loading and environmental factors [2]. In the recent years, the growth of the costs of repairing and reconstructing the pavement layers of the roads and airports, have made it necessary that comprehensive studies be carried out on the use of additives in composing asphalt mixtures to improve their mechanical properties against the dynamic loads. One of the major factors influencing the tolerability of the load by the asphalt pavement is the extent of the inter-grain keying and interlocking of aggregates. Glasphalt was first used in the model roads to measure their resistance against the water [3]. Glasphalt was extensively studied and researched at the turn of the 1970s and it was turned out that it's acceptable for using in many pavement layers. Subsequently, glasphalt was gradually abandoned because of the high costs of producing glass cullet [4]. Brittle glass materials which are crisp and fragile and rich in silicon – and are literally referred to as Hydrophile – show a smaller convergence in cohesion with asphalt. As a result, the sensitivity of these mixtures against water and humidity should be evaluated through relevant experiments, and if necessary, anti-stripping substances should be used [3]. The performance of the substances used in the materials is one of the concepts which the engineers have to deal with. When the waste materials are used, their efficiency also needs to be equivalent to or greater than the common materials [5]. The surface of glass particles is highly smooth and a great deal of silicon is included in it and this is what makes the glass cullet particles

* Corresponding author.
E-mail address: nkamboozia@civileng.iust.ac.ir (N. Kamboozia).

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immensely hydrophile. In this case, pavement layer with glasphalt would be reinforced and strengthened against damages. In order to solve this problem, additives would be used which can prevent the stripping of the asphalt while keeping the positive characteristics of the glass cullet in the asphalt surface. One of the materials that can prevent the stripping of the glasphalt surfaces is hydrated lime [6]. Based on the previous studies, it's clear that the glasphalt mixtures don't show a satisfactory performance against the phenomenon of stripping. The phenomenon of stripping took place in some of the studies carried out in New York and Baltimore, and was taken note of in the other studies [7]. Laboratory experiments by Hughes in 1990 showed that stripping in glasphalt would not be problematic, even though this study was confined to one type of aggregate substances, and it was only the hydrated lime that was used as an anti-stripping additive. The chemical substance of anti-stripping (usually 3–5% hydrated lime) was added to the mixture to increase resistance against stripping [8]. Studies indicate that using the glass cullet leads to the growth of the lifespan of glasphalt mixtures. In the present research, 2% of a certain type of lime was used as an anti-stripping factor so that it could increase resistance against stripping [9]. One research showed that asphalt pavements containing 10% crushed glass in glasphalt mixtures with Topeka gradation have been observed to perform satisfactorily [10]. In 2014, researchers present the parameter functions which can predict visco elasto-plastic behavior of glasphalt and conventional asphalt mixture in each of the separately analyzed levels of stress and temperature. By using these functions, it is not necessary to carry out laboratories test for determination the permanent strain and prediction the visco-elastoplastic behavior of glasphalt mixture [11].

1.2. Rutting phenomenon

A good pavement layer should offer a smooth surface for driving, sustain the high volume of traffic and convey the stress to the lowermost layers with minimum dissipation [12,13]. One of the problems of the asphalt pavement layers is the emergence of creeping in them. The phenomenon of creeping means the gradual occurrence of settlements and viable shifting without the emergence of cracks in the pavement layers under the constant loads. Permanent deformations which are manifestly represented as the rutting of the path of wheels are seen as the first criteria for setting out the plan of asphalt pavements [14]. The quality of Hot Mix Asphalt is one of the important factors which influence the efficiency of the flexible pavement layers. The surface rutting of the path of wheels can lead to the endangerment of the security of the roads. Therefore, excessive rutting, which is seen as the main factor behind the immature destruction of the roads and necessitates the repairing and maintaining the network of the roads will lead to the decreasing of the lifespan of pavement layer service [15,16]. The deep tracks (rutting) on the path of the wheels means a permanent deformation of the pavement layers that can increase with time [17]. The rutting of highways is a common phenomenon, because there are numerous lanes and a high volume of daily traffic. In the airports, we face the phenomenon of rutting to a smaller amount because the frequency of traffic is less and there are fewer lanes of movement. Asphalt concrete, under the influence of the traffic, is exposed to different strains [18]. The main reason for the creation of shear strains relates to the shear stress which takes place during the implementation in the pavement made of asphalt concrete. When the temperature of the surface layer is high, the possibility of the emergence of shear stress in the asphalt concrete would be greater [19]. The evaluation of the mixtures of asphalt concrete to protect them against the phenomenon of rutting on the path of wheels has turned into an important area of study in the recent years. This type of damage has taken place as a result of the consolidation and compaction of the asphalt mixture after the creation and implementation of plastic deformation as a result of the passage of vehicle wheels [20,21]. The excessive use of bitumen, aggregate, grained materials, riverbed-originated substances and round-cornered substances are among the conventional reasons related to the characteristics of the substances which leave a permanent influence over the deformation of the pavement [22]. Asphalt mixture design and analysis system is based on experiments that determine the potential of asphalt mixtures rutting. In AASHTO 2002 vehicles wheel path dent is estimated by the Eq. (1) [23]:

$$\frac{\varepsilon_p}{\varepsilon_r} = \beta_{r1} 10^{k_1} T^{K_2 \beta_{r2}} N^{K_3 \beta_{r3}} \tag{1}$$

where: ε_p: plastic strain at N load repetitions; ε_r: elastic strain (functional characterization of mixed); N: number of load repetitions; T: temperature in degrees Fahrenheit; K_i: non-linear regression factor; β_{ri}: parameter calibration.

1.3. Stiffness modulus

One of the important properties of asphaltic pavements is stiffness modulus. Bituminous mixture stiffness must be determined to evaluate both the load-induced and thermal stress and strain distribution in asphalt pavements [24]. Stiffness has also been used as an indicator of mixture quality for pavement and mixture design and to evaluate damage and age hardening trends of bituminous mixtures in both the laboratory and the field. The stiffness modulus is determined by use of the indirect tensile stiffness modulus (ITSM) test, repetitive tri-axial tests and sometimes repeated load uniaxial [1]. A practical model was developed to predict the stiffness modulus in pavement bearing capacity analysis. This model is a function of temperature and porosity. The general expression for the predictive model is given in Eq. (2):

$$S_m = (A_1 + A_2 V_V) e^{\left[\frac{T(A_3 + T)}{A_4}\right]} \tag{2}$$

where S_m is the indirect tensile stiffness modulus (MPa), V_v is the void volume content (%), and T is the test temperature (°C). The parameters of the expression are A_1, A_2, A_3 and A_4 [25]. Some institutions, including Shell and the University of Nottingham, have established prediction models for the stiffness modulus of asphalt mixtures that are used in their pavement design approaches. These models have been developed for several kinds of asphalt mixtures, except for HMAC (high modulus asphalt concrete) [26].

In this paper, nanotechnology zyco-soil was used as an anti-stripping in glasphalt mixtures and its effects on creep compliance and stiffness modulus of glasphalt mixture are investigated.

2. Experimental studies

2.1. Used materials

The aggregates used in this study were graded using the continuous type III and IV scale of the AASHTO standard [27] which is presented in Table 1. In producing the samples, the 60–70 bitumen of the Isfahan Refinery has been used. The characteristics of bitumen are inserted in the Table 2.

Table 1
Gradation of aggregates of HMA layers.

Sieve number	#200	#50	#8	#4	3/8″	1/2″	3/4″	1″
Sieve size (mm)	0.075	0.3	2.38	4.75	9.5	12.5	19	25.4
Type of aggregation	Percentage passing (%)							
Topeka	6	13	43	59	–	95	100	–
Binder	5	12	36	50	68	–	95	100