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Laboratory evaluation of Nano Al_2O_3 effect on dynamic performance of stone mastic asphalt

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Abstract

A part of different countries' budget in the world annually is spent on the restoration and reconstruction of pavements damages. Hence, by increasing the quality of hot mix asphalt, the pavement researchers are constantly trying to improve the quality of hot mix asphalt, greatly reduce the incidence rate of damages in the roads and delay the incidence time as much as possible. Many studies show that the quality of hot mix asphalt can be improved by using additives. Nano Al_2O_3 is studied as an additive in this research and also, in order to improve the hot mix asphalt strength against the damages, the type of stone mastic asphalt is examined. Stone materials gradation used in this study is the average gradation proposed by Asphalt Pavement Regulation of Iran Roads (Publication 234) for stone mastic asphalt with a maximum aggregate nominal size of 20 mm. The bitumen consumed is bitumen 60–70 in Tehran Pasargad Oil Processing Complex. In order to prevent the draindown phenomenon in stone mastic asphalt which occurred according to the space between aggregates, the cellulose fibers with the amount of 0.3% hot mix asphalt weight are used to produce the hot mix asphalt. The effect of Nano Al_2O_3 additive on dynamic performance of stone mastic asphalt is investigated through dynamic creep test, wheel track test and indirect tensile fatigue test. Results show that addition of different percentages of Nano Al_2O_3 is capable to improve the dynamic performance of stone mastic asphalt, significantly.

Keywords: Stone mastic asphalt; Nano Al_2O_3; Rutting; Dynamic creep; Fatigue

1. Introduction

The asphalt concrete is one of the materials widely used for pavement of roads and airports. The researchers and engineers are constantly trying to improve the performance of asphalt pavements. The pavement of roads as the surfaces that are exposed to the frequent loadings of heavy axes should have enough strength against the fatigue, cracking, creep and skid resistance [1].

Hot mix asphalt in the pavement structure is used as a surface layer to distribute the stress caused by the loading and protect the unprotected bottom layers against water effect. Hot mix asphalt should be resistant against the weather effects and stand up against the permanent deformation and cracks caused by loading and environmental factors in order to be able to do both duties efficiently in pavement design lifetime [2].

1.1. Stone mastic asphalt

Stone mastic asphalt is gap-graded hot mix asphalt consisting of two parts of coarse aggregate and bitumen-filled mortar (bitumen mix, filler and stabilizing additives). This hot mix asphalt should have coarse aggregate

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structure with stone on stone contact. In this type of hot mix asphalt, the stones are referred to the materials left on the 4.75 mm sieve, also 2.36 mm sieve can be used for this purpose [3].

Stone mastic asphalt is mainly used as binder course and the crowded roads with heavy axial load. This hot mix asphalt due to the use of high-grade and 100% crushed materials, relatively high consumption of the aggregates larger than 4.75 mm compared to the continuous-graded, with stone on stone contact structure which increases the strength and resistance of hot mix asphalt against rutting and permanent deformations and because of the relatively high consumption of bitumen, has reliability and higher durability.

Bitumen used in the stone mastic asphalt should be as the classified pure bitumen according to penetration degree, or functional or modified bitumen. The amount of consumed bitumen in these mixtures is at least 6% and usually more than the amount of bitumen in continuous-graded hot mix asphalts. The reason for the high consumption of bitumen in the mixtures is the gap-gradation and relatively large amount of filler. In order to prevent the phenomenon of separation or draindown, the stabilizing additives can be used. Any additives that can cause any improvement by promoting the properties of bitumen or bitumen mortar used in stone mastic asphalt in one or more of the following cases can be used [3]:

I. The permanent deformation.
II. Fatigue & Low Temperature Cracking.
III. Economic issues, particularly the reduction of required thickness to design.

1.2. Damages of asphalt pavements

Pavements are usually affected by various factors which have effect on their life. Since a road is passing through different areas with different traffic volumes, traffic types and rainfall rates, therefore, the flaws and defects occur in different points of the road which will result in the road rapid damage in the case of lack of attention, evaluation and restoration.

Among the most important damages that occurred during the useful life of the pavement, the permanent deformations in the vehicles' wheel track (rutting) and the cracks caused by the fatigue can be mentioned. Since for restoration and reconstruction these flaws and defects, high costs should be spent, so the early prevention is usually more affordable. In order to avoid such damages, the pavement materials should be selected as they have adequate strength and stability [4].

Deep wheel track (rutting) is the permanent deformation of pavement layers that can be increased with the passage of time. Deep wheel track resulted from the deformation in one or several layers of the asphalt pavement. On the one side, there is a deformation that is limited to the surface layer which is called "surface rutting", while in another side, there is a deformation in which the main part of the deformation occurred in the sub base layer and is called the structural rutting [5]. A view of the deep wheel track is shown in Fig. 1.

Evaluation of asphalt concrete mixtures in order to protect them against the phenomenon of wheel track rutting has become an important research field in recent years. This type of damage occurs as a result of consolidation and compaction of hot mix asphalt after the construction and development of plastic deformation caused by the passage of vehicle wheels over time [6].

The cracks caused by fatigue usually occur where the asphalt pavement is affected by the frequent affected loading. Cracking is directly related to the increased tensile strain under the asphalt layer and begins when the strain passes the threshold limit. Despite the efforts taken, determining the amount of this threshold limit has not been successful. The fatigue process includes three steps:

I. Start of damage with fatigue cracks.
II. Cracks growth in the uncracked areas to the pavement component weakening step.
III. Final and sudden failure of pavement component.

Fatigue lifetime of a sample or component is the number of repetitions required for the sample failure and depends on many variables such as stress value, stress direction, the waveform and oscillation, the weather conditions and construction conditions. Small changes in the sample position might cause significant changes in the structure fatigue behavior and this is complicated the scientific and mathematical prediction of this phenomenon. Hence, the designers use their experiences on practical samples more than laboratory studies. However, the laboratory studies are essential to understand the material behavior and these tests can result in a design measure.

Fig. 1. A view of the rutting occurrence in asphalt pavement.