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Design of Flexible Pavement Reinforced with Steel Fiber

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ABSTRACT: *Permanent deformation, often known as rutting, happens as a result of repeated loading from high traffic, which causes gradual buildup of permanent deformation under repeating tyre pressures. In engineering practise, asphalt mixtures are blended with steel fibres to enhance traditional asphalt concrete pavement performance, decrease road maintenance costs, and extend the life of the pavement. To replicate the performance of flexible pavement with life, two slabs with dimensions (300*300*50) mm were produced for rutting tests with two percentages of steel fibre content (0.0, 0.2) percent. The findings revealed that the rutting value in the control mix is (27.04) mm, but the rutting value at 0.2 percent steel fibre content and 5.5 percent asphalt content is (22.42) mm. At 0.2 percent steel fibre concentration, the dynamic stability of the asphalt mixture increases by around 6.4 percent. The development of a three-dimensional finite element model for flexible pavements is carried out using ABAQUS (6.14-4) to mimic laboratory testing. A statistical analysis is used to determine the compatibility of lab models and numerical models, as well as to evaluate the possibilities of employing the numerical technique to anticipate further improvements in the pavement body.*

KEYWORDS: *Steel Fiber, Asphalt, Aggregate, Mineral Filler, Bituminous etc.*

INTRODUCTION

Asphalt cement modifiers have been used in pavement technology to improve pavement performance and minimise many forms of pavement distress, the most frequent of which are rutting, low temperature cracking, fatigue cracking, stripping, and hardening. Thomas et al. employ fibre as one of the additions for this reason (1999). The primary roles of fibre as reinforcing materials are to give tensile strength to the final composite, which may improve the amount of strain energy that can be absorbed throughout the mix's fatigue and fracture processes. Mahrez and colleagues (2003). [The addition of conductive fibres to asphalt concrete allows for multifunctional applications such as structural health self-monitoring, self-healing, and snow and ice removal from the pavement surface. Huang et al. measured the electrical conductivity of conductive HMA filled with micron size steel fibre, aluminium chips, and graphite. They also looked at the feasibility of linking the electrical characteristics of HMA mixes to their laboratory mechanical properties.Among the conductive additives evaluated of mineral fibers, steel and carbon fibers generally retained or improved the laboratory performance of HMA mixtures, whereas graphite, due to the need for higher content, significantly altered the performance of HMA mixture and especially compromised

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the cracking resistance. Sercan Serin (2012) used different rates of steel fiber (0%, 0.25%, 0.50%, 0.75%, 1.0%, 1.5%, 2.0%, 2.5% were prepared and the optimum value for fiber rate that results in the best stability value was determined as 0.75%. Steel fibre additions can be employed in flexible pavement binder courses due to their favourable stability influence, according to the study's findings. Quantao Liu et al. (2009) found that increasing the steel fibre volume content to 11% enhanced the indirect tensile strength (ITS) of porous asphalt concrete. Increasing the number of fibres in the mixture reduces the indirect tensile strength because too many fibres diminish the mastic film thickness, resulting in poor adhesion between the asphalt components.

MATERIAL

Characterization: The materials used for this investigation are commonly utilised in asphalt pavement. The standards of the SORB specification (2003) were deemed to have been met. The next sections address physical and chemical characteristics.

Asphalt: Cement This study's binder is asphalt cement (40-50) penetration grade obtained from the Daurah refinery facility. The ideal asphalt content is (5.5) percent by weight of total mix, and this figure is employed in this study. The asphalt's physical characteristics.

Aggregate: It is made up of crushed quartz, strong, durable grains that are free of harmful amounts of clay, loam, and other harmful components. This material is commonly used in asphalt concrete mixtures in Baghdad. The coarse and fine aggregates used in this project were sieved and recombined in the right proportions to match the specification's wearing course gradation (SCRB, R/9 2003).

Mineral filler: One type of mineral filler (ordinary Portland cement) is used. It is thoroughly dry and free from lumps or aggregations of fine particles.

Steel fiber: Straight steel fibres made by Bekaert Corporation were employed in this investigation. Each steel fibre is roughly 175 mm in diameter and 13 mm in length (Roux, 1996). During the drawing process, a thin brass coating is added to the fibres..

Preparation of slab specimens: A rectangular specimen with dimensions of (300 mm) in length, (50 mm) in height, and (300 mm) in width is constructed. Steel rectangular mould (300 mm) in length, (50 mm) in height, and (50 mm) in width (300mm). A hot plate is used to heat the mould to a temperature of (120-150oC). At a temperature of 160oC, the asphalt mixer thoroughly mixes the mixture's components for around two minutes. The asphalt mixture is deposited in the preheated mould, and the temperature of the mixture immediately prior to compaction is (160oC). After that, the mould assembly is placed on the roller compaction machine. and the specimen is compacted at constant pressure load, (0.54) MPa, passing through the monitoring arm (arm convex) on the form multiple times to achieve the appropriate density ratio and height. The slab is allowed to cool at ambient temperature before being tested with a wheel tracking equipment.

PERFORMANCE TEST FOR RUTTING

Permanent deformation, often known as rutting, is a complicated phenomena that presents substantial hurdles in terms of performance measurement. It is one of the most common and severe types of discomfort on hot-mix asphalt layers. Permanent deformation can cause ponding of water in tyre tracks, which can be a severe traffic hazard in rainy weather. Rutting can also result in poor ride quality, which can raise vehicle running expenses.Wheel Track Machine and Rut Depth Test the Wheel tracking machine in the highway laboratory in the Petroleum R & D Center is used for rut depth test of asphalt slab sample. The wheel of Machine moves at the speed of 42 passing per minute, which is made of rubber tire of 5 cm width and the pressure of 6.5 kg/cm^2. The test lasts one hour, thus the total number of passes is 2520. The Machine is aided by a computer that can generate a report on the link between the number of passes and the rut depth. At the 1st, 5th, 10th, 15th, 30th, 45th, and 60th minute, the computer records the number of passes and the rut depth. The capacity of asphalt concrete pavement to withstand rutting is characterised by Dynamic Stability (DS), which represents the number of passes required to generate one millimetre of rut depth. The definition of Dynamic Stability is as follows:

DS = (L60 – L45)/ (D60 – D45)

FINITE ELEMENT MODELING BY ABAQUS

The finite element method (FEM) is a numerical analytic tool that has been proposed for use in this work to calculate the stress, strain, and deflection of the pavement layers. Finite element analysis is one of the most widely used numerical approaches for obtaining an approximate solution to complicated problems in a variety of engineering domains. The commercial finite element code ABAQUS 6.14-4 is utilised. The simulation approach is implemented in steps. The precise shape and dimensions of the experimental model Al-Qadi et al. (2004) were first obtained in order to develop the numerical model. Second, the simplest materials model (linear Elastic behaviour) is utilised to introduce pavement structure materials behaviour. Third, dynamic loading is used to provide a true simulation of the experimental model. Because the primary goal of the ABAQUS Version 6.14-4 programme user is to represent a certain scenario or solve a specific problem and then discover a solution, it becomes important to engage with the programme in its own language, which involves developing a model and then analysing it. These modules should be used to define the geometry, material qualities, and other physical attributes of the model before submitting it for analysis. The materials employed in this investigation' attributes are summarised. These attributes apply to the program's input parameters. The elastic modulus (E), Poisson's ratio (), and density are the parameters in question.

Figure 1

RESULTS

Effect of steel fiber on rutting the rutting: In the case of the control mix, rutting rose by (27.04 mm). It is possible to notice that rutting decreased by (22.42 mm) at 0.2 percent steel fibre content with an ideal asphalt concentration of 5.5 percent. The rutting per pass is reduced by about 6.6 percent as compared to the control mix. In addition, the number of passes required to produce failure increased by about 28.6 percent when compared to the control mix, and dynamic stability improved by approximately 6.4 percent at 0.2 percent steel fibre content for asphalt mixture.

Finite Element ABAQUS result: The results of the ABAQUS programme may be produced by entering certain parameters for each model, such as diminution, modules of elasticity, poison ratio, and time for number of passes, and then the laboratory results using the ABAQUS model are simulated. Permanent deformation, two models, one for control mixture and the other for 0.2 percent steel fibre, are among the results.

CONCLUSIONS

Based on the obtained results and limitations, the following points could be drawn:

- The addition of steel fibres increases the number of passes required to achieve the same rutting value (value in the case of the control). In the case of the control mix, rutting rose by (27.04 mm). While the rutting decreased by (22.42 mm) with 0.2 percent steel fibre content and 5.5 percent optimal asphalt composition.
- The number of passes to cause failure increased by about 28.6% as compared with control mix.
- The dynamic stability is increased about by 6.4 % at 0.2% steel fiber content for asphalt mixture.
- The simulation of lab models using the ABAQUS programme demonstrates that the programme agrees well with finite elements.

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